Vol. 5 JUNE, 1922 No. 6

Journal
of the
American Ceramic Society
Ceramic Abstracts and The Bulletin

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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Single Numbers, Seventy-five Cents

Eight Dollars per Year. (Foreign postage additional.)

Entered as second-class matter, July 15, 1918, at the Post Office at Easton, Pa., under the Act of March 3, 1879

Accepted for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized August 16, 1918

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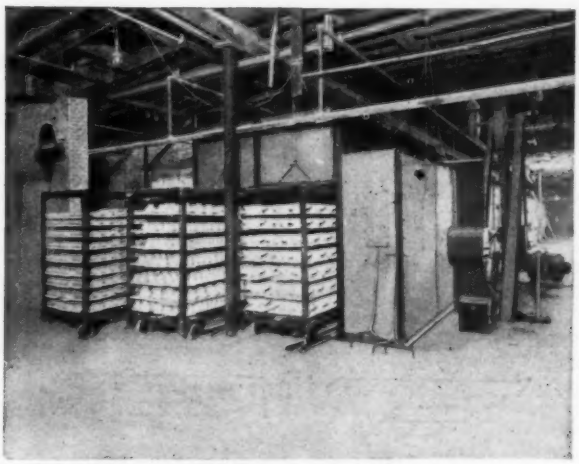
"HURRICANE" DRYERS



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JOURNAL

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A monthly Journal devoted to the arts and sciences related to the silicate industries.

Publication Office: 211 Church St., Easton, Pa.
Editorial Office: Lord Hall, O. S. U., Columbus, Ohio.
Advertising Manager: L. R. W. Allison, 170 Roseville Ave., Newark, N. J.
Committee on Publications: R. H. MINTON, Chairman; H. F. STALEY, CHESTER H. JONES, E. W. TILLOTSON, ROSS C. PURDY.
Editor: ROSS C. PURDY; **Assistant Editor:** EMILY C. VAN SCHOICK; **Associate Editors:** L. E. BARRINGER, E. W. TILLOTSON, ROY HORNING, R. R. DANIELSON, A. F. GREAVES-WALKER, F. H. RHEAD, H. RIES, R. L. CLARE.

Vol. 5 **June, 1922** **No. 6**

ORIGINAL PAPERS

DATA ON THE OPERATION OF A CONTINUOUS TUNNEL KILN AT THE PLANT OF THE A. C. SPARK PLUG COMPANY[1]

BY SAMUEL J. MCDOWELL AND PERRY D. HELSER

ABSTRACT

This kiln has total length of 75 feet and interior width of 2 feet 8 inches. Design is based upon the idea of firing small thin mass at a rapid rate, only 12 hours being required for the burning operation. The ware, spark plug porcelain insulators, is passed through in a single, unprotected, horizontal tier, being subjected to direct fire. The kiln is operated at cone 18 half down. City gas is used, with burner equipment which is a modified form of Surface Combustion.

The initial cost is low. The kiln is of simple construction, permitting rapid heating and cooling. Output depends upon ability of individual pieces of ware to safely absorb heat necessary for their vitrification. The process is patented.

Introduction

The data given in this paper has been obtained from tests and observations on the tunnel kiln installed at the plant of the A. C. Spark Plug Co., Flint, Michigan. It covers a period of over two years' successful operation, first at cone 16 and later at cone 18.

This kiln is used for firing spark plug porcelain insulators. It is probably unique for several reasons:

1. The kiln proper is but 60 feet long, with an additional wind tunnel of 15 feet, making a total length of 75 feet. The interior width is 2 feet 8 inches.
2. A high temperature is obtained for a kiln of such length.
3. The kiln is open or direct fired.

[1] White Wares Division, St. Louis Meeting, Feb. 28, 1922.

4. The ware is passed through in a single horizontal tier subjected to direct fire, that is, not protected by saggers.

5. The ware is advanced continuously, in contrast to the type in which the ware progresses more or less intermittently.

6. The construction is simple. The cost of installation is, therefore, comparatively low. This simple construction allows the kiln to be brought to a maximum temperature in a minimum length of time without detrimental effects to the structure.

7. It is possible to closely control the composition of the kiln atmosphere, maintaining either oxidizing or reducing conditions.

8. The kiln, throughout its length, is supported on concrete arch construction. This permits access to the space under the cars at all times. It also prevents possible overheating of the steel framework of the cars.

Description of Kiln

Preheating Zone.—The preheating zone is lined entirely with high grade fire brick. The walls are built of fire-brick and Nonpareil insulating brick. The arch is built of a double rowlock of fire-brick with a covering of insulation brick.

Drop arches of fire-clay shapes act as baffles to force the hot combustion gases down around the ware as the preheating progresses.

Hot Zone.—The hot zone walls are built of silicon carbide brick, high grade fire brick, and Nonpareil insulating brick. The arch is similarly built of carborundum brick, high grade fire brick and insulating brick.

There are nine burner openings in each side. The burner orifices open into the kiln slightly above the level of the ware and at such an angle as to allow the flame to impinge upon the arch.

At the end of the hot zone is a soaking or retarding zone of similar side wall construction, but with hollow arch construction of carborundum blocks filled with Kieselguhr. These blocks form a drop arch immediately over the ware to prevent the hot gases from escaping toward the cooling end of the kiln.

Cooling Zone.—The cooling zone is composed of three sub zones:

(1) *Muffle Cooling.*—The top of the muffle cooling zone is built of fire-clay shapes and corundum slabs, so arranged as to give a continuous air duct leading back and forth over the ware from an opening in the cool end of this sub zone to a stack in the hot end, where the hot air escapes.

(2) *Water Cooling.*—The walls and arch of the water cooling zone are built of second grade fire brick. Coils are placed immediately above the ware and water passes through them continuously.

(3) *Direct Air Cooling.*—This was not a part of the kiln as originally designed. However, the cars and ware came out too hot to comfortably

handle and a wind tunnel of 15 feet was added. The walls are built of brick and the top is constructed of sheet metal.

An air duct leads from a fan to two openings through the sheet metal top of the wind tunnel and near the exit end of the kiln. The air from this fan is prevented from entering the kiln proper by a flap which brushes on top of the ware.

A sand trough runs the entire length of the kiln on either side. It is built of angle iron and is bolted to the concrete through slotted holes to allow expansion.

Pusher.—The pushing mechanism consists of an endless chain extending six feet into the kiln under the center of the cars. The chain carries dogs four feet apart. Each of these dogs in turn engages the rear axle of the last car and pushes forward the entire train. The chain is propelled through various speed reducing mechanisms by a continuously operating 3 H.P. motor. The power actually required is 1 H.P. The speed reducing mechanism is so arranged as to permit control of the rate of travel through the kiln. This rate may be varied from a minimum of five hours to a maximum of thirty hours elapsed time for travel through the kiln.

Burner Equipment.—The burner equipment used is a modified application of the Surface Combustion low pressure system. In this system the air is supplied by a Root's positive pressure blower. The gas is reduced to atmospheric pressure by means of a regulator. The air and gas are then automatically mixed in any desired proportion. This explosive mixture is forced through the burner orifices and impinged upon the arch of the kiln.

Fuel.—The fuel used is artificial city gas. This is a mixture of coal gas and water gas enriched with oil to insure a product having a heating value of approximately 550 B.t.u. per cubic foot.

Burner equipment is on hand for the application of fuel oil, the possibilities of which we plan to thoroughly investigate.

Pyrometer Equipment.—The pyrometer equipment consists of two base metal couples in the preheating zone, three in the cooling zone, and three platinum couples in the hot zone. These couples are connected to an indicating pyrometer which is read and recorded every thirty minutes.

Figure 1 shows a car of ware entering the kiln.

Cars.—The cars are 4 feet in length and 2 feet 6 inches in width. Steel aprons attached to either side of the cars drag through the sand in the sand-seal trough and prevent the hot gases from coming into contact with the wheels and rails.

Refractory blocks are placed along the edges of the steel car frame, while in the center insulating brick are used. Additional refractory blocks cover the entire car.

The trays are 15″ x 16″ x 2″ outside dimensions and are approximately 1″ thick. They are composed of fire-clays and grog and are formed on a

sagger press. The life of the trays is lengthened because of the fact that they carry only the weight of the ware in them.

In the event of firing ceramic ware of sufficient base area to stand unsupported, the trays might be dispensed with and the ware placed directly upon the car, thus eliminating the use of saggers or the like.

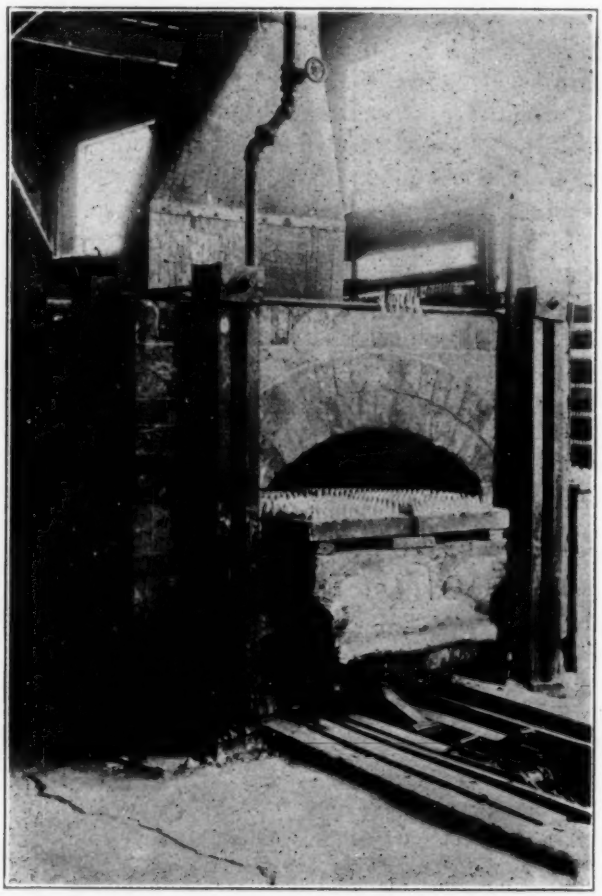


FIG. 1.

Ware.—The ware consists of one-fire, glazed porcelain spark plug insulators approximately $2^1/_2''$ in length by $^3/_4''$ in diameter. They are placed in the trays with unglazed shoulders touching.

Standard Conditions of Operation.—The kiln was put into operation in November, 1919, at a temperature of cone 16 touch. Later a change in body composition necessitated a temperature of cone 18 half down, and since that time the kiln has been operated at this latter temperature.

The kiln is operated on a twelve-hour schedule, that is, twelve hours are required for a car to pass from the entrance to the end of the kiln proper (60 feet), at which location access is gained to the ware. This speed means that the car advances through the kiln at the rate of one inch per minute.

Figure 2 shows a car of ware emerging from the wind tunnel.

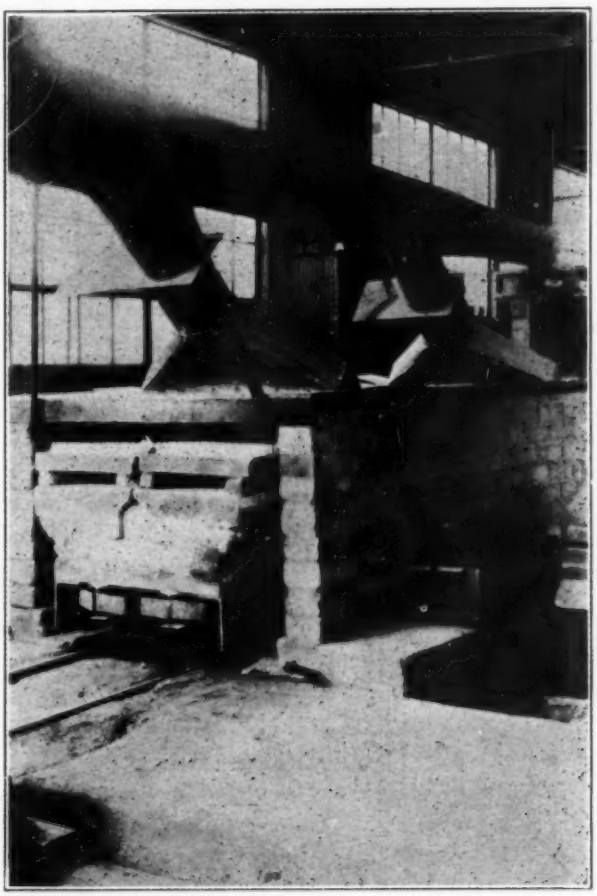


FIG. 2.

Figure 3 shows the temperature curve throughout the length of the kiln. These temperatures were obtained by means of a thermo-couple projecting up through the bottom of a car to the level of the ware. This car was passed through the kiln in the usual manner to a maximum temperature of cone 18 half down. Temperatures were recorded every twelve minutes, or every foot of travel. This curve, therefore, shows the actual continuous heat change to which a piece of ware is subjected.

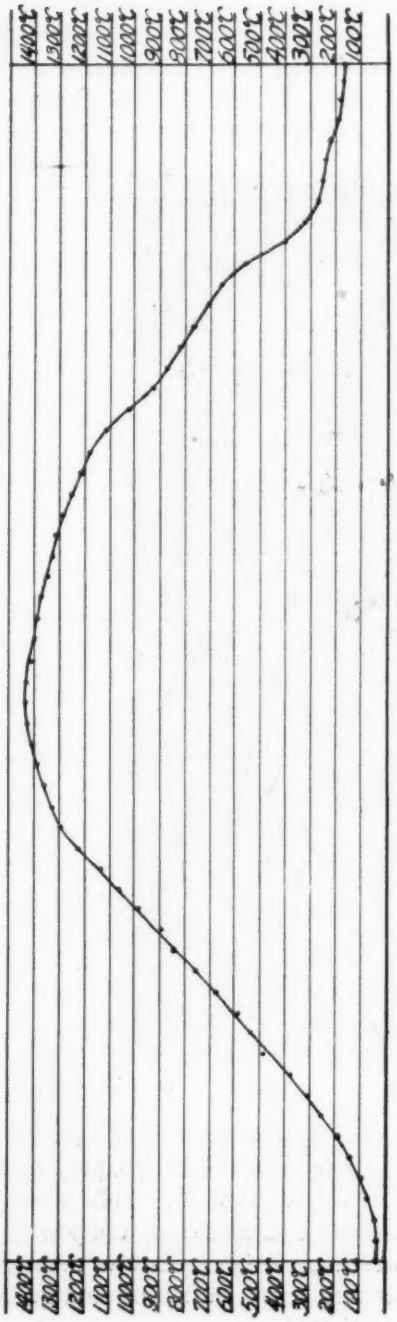


FIG. 3.

Cones show practically no variation from side to side of the car top. Cones 17 and 18 are placed on cars where they may be seen from the entrance opening of the kiln in order to serve as a check on firing. The operator watches the cones as closely as he does the pyrometer.

The burner equipment is adjusted to maintain a desirable kiln atmosphere. The combustion gases pass over and around the ware as it advances through the preheating zone and are finally carried off by a stack at the entrance of the kiln. No serious attempt has been made to utilize the waste heat.

The temperature of the gases in the stack is approximately 100°C, the gases being diluted with air from the entrance of the kiln, which accounts for their low exit temperature.

The absence of a complicated construction in the kiln permits a more rapid elevation of the temperature upon lighting than is usually the case with tunnel kilns. Approximately 36 hours elapse from the time of lighting until the ware is started in.

The idea in designing a continuous tunnel kiln of such small dimensions was based upon firing a small mass at a rapid rate. Attempts have been made to fire comparatively large masses of ware at a rapid rate, but with disastrous results.

The benefits of this kiln are limited to the firing of ceramic wares composed of such materials and of such dimensions or so grouped as to

be capable of absorbing sufficient heat to produce vitrification in a comparatively short length of time.

It is a very desirable type of kiln in which to fire bodies containing those synthetic fluxes, which are susceptible to objectionable crystalline growths unless properly cooled.

The flexibility of control of the kiln atmosphere enables the maintenance of oxidizing, neutral or reducing conditions as the ware may demand.

This kiln was originally built more or less as an experimental unit, but its operation was so successful that it has been used in production almost continuously since its installation.

With gas at 87 cents per thousand cubic feet, the cost of the burning operation is slightly less than the cost of burning in coal fired periodic kilns. And greater uniformity of product is obtained due to uniform heat treatment.

A new kiln of similar design has been constructed and has just recently been put into operation. This kiln is 87 feet in length and has an interior width of 5 feet 2 inches, or twice the width of the original kiln. Uniform temperatures are also obtained over this greater width. This kiln only requires approximately one-third more fuel to operate than the original kiln and yet has more than twice the capacity.

Protection on both design and process has been allowed by the U. S. Patent Office.

In conclusion, the writers wish to express their appreciation to Mr. Taine G. McDougal for his assistance in the preparation of this paper.

Discussions

BY C. B. HARROP:—For the firing of a shallow layer of small size ware, made from a body mix that will stand rapid heating and cooling, the above-described kiln is undoubtedly a real success. However, for capacities such as are being secured from some of the other tunnel kilns firing sanitary ware, general ware and electric porcelain, this type of kiln would undoubtedly be out of the question.

The writer has been much interested in this kiln and in reports that have filtered in concerning it, ever since it was put into operation, although for some reason the construction and operation of the kiln have always been kept close secrets by the owners.

The *surface combustion* firing equipment is probably responsible to a large extent for the success of the kiln. Any other system of fuel application would undoubtedly result in so much greater volumes of combustion gases that the temperature at the charging end of the kiln would be excessive and serious damage would occur to the entering ware. The *surface combustion* principle of firing gives an intense temperature in a restricted space which is absolutely necessary in a kiln of this length.

If the authors had given more real operating data their paper would be of far greater practical value. It would be very interesting to know:

(*a*) Tonnage or number of pieces fired per 24 hours.
(*b*) Cubic feet of gas required per 24 hours.
(*c*) Total power required to operate kiln.
(*d*) Labor required to operate kiln.
(*e*) Cost of repairs—average over a long period.
(*f*) Approximate total cost of kiln.

By A. W. Buckingham:—The following discussion consists mainly of questions on points which should be emphasized in view of the fact that this kiln differs in a number of respects from the other makes.

Two features of this kiln illustrate a tendency in present day kiln construction which make for better control: First, the cross-section of this kiln is as small as possible, consistent with the production required.

Second, the large number of burners in the firing zone undoubtedly permits considerable flexibility in "soaking" time.

Other points have occurred in reading this paper which we believe the author should have brought out:

1. What is the approximate cost of the different kilns?

2. It is natural to suppose that heating up and cooling down a tunnel kiln would cause more or less wear and tear on the structure. The author states that after two years of operation there has been very little damage to the kiln on account of this intermittent operation. To what particular features of the construction or operation does he attribute this?

3. The width of the kiln is given in the paper but not the height of the crown of the arch above the deck of the kiln car. It would be interesting to know how much air space there is above the material being fired.

4. Drop arches in the preheating zone should serve as an effective baffle provided they extend down fairly close to the deck of the kiln car. How much below the crown of the main arch do these baffles extend?

5. Manufacturers of this grade of ware would be interested in learning what the unit fuel consumption is, that is, cubic feet of gas per ton of ware, etc.

6. The method of taking temperature for the full length of the kiln at 12 minute periods is a novel one and certainly should be very accurate. Does the author suggest this as being a practical method of taking temperatures at frequent intervals throughout the day?

7. The second installation is described as being about twice the width of the smaller one. What is the total burning time in the longer kiln as compared to the 12 hours for the first installation?

By A. F. Greaves-Walker:—The kiln described is what would be termed a "Sport" in botany. It will do excellent work on such wares as

spark plug porcelains which are very small or on wares of thin section, or it could be used for decorating on some classes of ware.

It is an unqualified success; is cheap to construct and easy and cheap to operate. Furthermore, it is the ultimate in quick results.

It is out of the question, of course, to consider the use of this type of kiln for the vast bulk of ceramic products. The further development of its limited use is a question of the future.

COMPARATIVE TESTS OF AMERICAN AND FOREIGN TABLEWARE[1]

By H. H. Sortwell[2]

ABSTRACT

The absorptions, porosities, and bulk specific gravities are given. It was found that the American wares were superior to the English, French, German, and Japanese wares tested in resistance to either crazing or sudden temperature changes. The American hotel wares withstood much greater impact than the imported hotel wares, and the domestic earthenware and china for household use was superior to the foreign chinas tested, which were brittle. The resistance of hotel wares to chipping at the edge appeared to depend more on the design of the edge and the angle of inclination of the rim, than on the inherent properties of the bodies. All of the glazes were found to be unaffected by boiling in alkaline solutions for a period of twenty-five hours.

Introduction

In connection with the devising of specifications to be used by the various government purchasing agencies in the selection of tableware, the Bureau of Standards has made a number of tests on a large variety of wares.

The devising of specifications of quality involves two problems: first, the study of various tests to develop simple, practical methods which will give a criterion of the service to be expected from the wares tested; and second, the study of a large number of wares by these tests to determine limits of quality which will serve as an aid to the purchasing agent in making his selections, and at the same time be fair to the potter and protect him from unreasonable demands.

This paper consists of an exposition of the tests studied, and a presentation of the data obtained by conducting them on a large variety of wares. For the purpose of comparison, representative French, German, English, and Japanese products which in ordinary times have been imported in large quantities, were included. Some of the wares were acquired by purchase, some were contributed by potters, and a number were obtained from a supply depot of the United States Public Health Service. The data resulting from the preliminary work to the present time refer to absorption, porosity, and bulk specific gravity, resistance to crazing and sudden temperature change, resistance to impact, resistance to chipping, and resistance to alkaline solutions.

Due to the limited number of samples tested these results can not be taken as an accurate criterion of the continuous output of the various potteries, but they are such results as would be obtained in testing lots of ware for purchase by specification, and they show the distinct differences in the different types of ware tested.

[1] Published by permission of the Director, Bureau of Standards.

[2] Received April 1, 1922.

Absorption, Porosity and Bulk Specific Gravity

In determining absorption, porosity, and bulk specific gravity boiling the pieces in water one hour followed by a soaking period was considered a sufficiently accurate means of saturation for the practical, comparative test desired. About forty grams of pieces approximately one inch square broken from the centers of plates were used in each determination. After drying at 110°C the pieces were weighed, boiled in water one hour, and allowed to remain in the water eighteen hours after the boiling. By this procedure the pieces were boiled on one day from three to four P.M. and the following morning at ten A.M. were weighed suspended in water, after which they were wiped off with a damp cloth and weighed again.

The computations were made by means of the following formulas:

$$\text{Per cent absorption by weight} = 100 \times \frac{W - D}{D}$$

$$\text{Per cent apparent porosity by volume} = 100 \times \frac{W - D}{W - S}$$

$$\text{Bulk specific gravity} = \frac{D}{W - S}$$

in which D is the dry weight, S the weight of the saturated pieces suspended in water, and W the weight of the pieces saturated with water.

The results given in Table I are averages for six plates of each make, and show that the American hotel chinas are not in some cases fired to zero absorption. One ware, No. 10, had an absorption of 1.4 per cent. Two of the American hotel wares were earthenware as shown by absorptions of 7.9 and 9.8 per cent, and one, No. 11, was about half way between the earthenware and vitreous china in absorption.

The English hotel wares were not vitrified, the absorptions ranging from 2.7 per cent to 6.0 per cent, while the French and German hotel wares were completely vitrified to a glassy structure.

The American earthenware, commonly called semi-porcelain or semi-vitreous china, varied in absorption from 7.4 per cent to 10.2 per cent. The one domestic vitrified ware for household use included in the work was practically the same as the hotel ware made by the same pottery. All of the imported china for household use was completely vitrified and of glassy fracture.

In general a distinct difference was noted between the American vitreous wares on the one hand and the French, German, and Japanese wares on the other. The domestic bodies had a comparatively granular structure indicating that fusion and solution had not progressed as far toward forming a homogeneous glass as in the imported wares which were all of a glassy

TABLE I

RESULTS OF ABSORPTION, POROSITY, BULK SPECIFIC GRAVITY, IMPACT, AND CHIPPING DETERMINATIONS

No.	Type of ware	Ave. % abs.	Ave. % por.	Ave. bulk sp. gr.	Ave. impact energy ft. lbs.	Ave. thickness at break in inches	Ave. impact energy to chip ft. lbs.
1	Hotel ware, rolled edge	0.0	0.0	2.36	0.200	0.213	0.400
2	Hotel ware, rolled edge	.0	.0	2.30	.250	.215	.250
3	Hotel ware, rolled edge	.0	.0	2.30	.300	.212	.250
4	Hotel ware, rolled edge	.2	.4	2.40	.300	.194	.275
5	Light hotel ware, plain edge	.0	.0	2.40	.175	.190	.125
6	Hotel ware, rolled edge	.6	1.4	2.38	.275	.234	.350
7	Hotel ware, rolled edge	.8	1.9	2.38	.275	.187	.275
8	Hotel ware, rolled edge	.3	.7	2.38	.200	.222	.275
8*a*	Heavy hotel ware, plain edge	.3	.7	2.38	.250	.259	.325
9	Hotel ware, rolled edge	.0	.0	2.30	.150	.172	.125
10	Hotel ware, rolled edge	1.4	3.2	2.33	.400	.203	.225
11	Hotel ware, rolled edge	4.8	10.5	2.16	.225	.246	.125
12	Hotel ware, rolled edge	7.9	16.2	2.05	.250	.156	.100
13	Heavy hotel ware, plain edge	9.8	19.9	2.03	.225	.238	.200
14	English hotel ware, rolled edge	3.4	7.7	2.33	.150	.215	.300
15	English hotel ware, rolled edge	6.0	13.5	2.23	.150	.193	.225
16	English hotel ware, rolled edge	2.7	6.1	2.23	.125	.190	.200
17	English hotel ware, rolled edge	5.1	10.8	2.13	.175	.157	.150
18	French hotel ware, plain edge	.0	.0	2.18	.100	.194	.100
19	German hotel ware, rolled edge	.0	.0	2.33	.125	.168	.375
20	German hotel ware, rolled edge	.0	.0	2.35	.100	.214	.125
21	Household ware, semi-vitreous	8.5	17.1	2.01	.175	.155	..
22	Household ware, semi-vitreous	10.2	20.3	1.98	.175	.184	..
23	Household ware, semi-vitreous	7.4	15.2	2.05	.175	.162	..
24	Household ware, semi-vitreous	8.4	17.1	2.04	.200	.145	..
25	Household ware, semi-vitreous	7.9	16.2	2.06	.200	.162	..
26	Household ware, semi-vitreous	9.6	19.2	1.99	.200	.182	..
27	Household ware, semi-vitreous	8.7	17.5	2.03	.175	.154	..
28	Household ware, semi-vitreous	8.2	17.2	2.10	.175	.159	..
29	Household ware, vitreous	.0	.0	2.32	.225	.160	..
30	Japanese household ware	.0	.0	2.23	.100	.180	..
31	Japanese household ware	.0	.0	2.29	.100	.188	..
32	French household ware	.0	.0	2.20	.075	.122	..
33	French household ware	.0	.0	2.25	.150	.134	..
34	German household ware	.0	.0	2.38	.150	.150	..
35	German household ware	.0	.0	2.35	.150	.110	..

nature and of corresponding translucency. This difference in body structure has an important bearing on the properties of the wares as shown by other tests.

The vitrified wares varied in bulk specific gravity from 2.20 to 2.40, the American earthenware was uniformly about 2.00, and those wares lying between the two in absorption and porosity had intermediate specific gravities.

Crazing Test

In the selection of a test for crazing several methods which have been formerly used were tried. Repeated transfer of ware from boiling water to ice water has sometimes been used for such a test.[1] Since the strains which the pieces undergo in this treatment are equaled in a short time by the ware passing through the modern dishwashing machines this test is not severe enough to approximate conditions of long usage. Many vitreous and semi-vitreous plates were passed from boiling water to ice water and vice versa twenty-five times without the occurrence of any crazing whatever. To be valuable in differentiating between wares in regard to crazing tendency this treatment would have to be repeated such a large number of times as to make its use tedious and impractical.

The test used by Ashley[2] consisted of chipping the edges of plates and boiling them eight hours in a saturated solution of sodium chloride, after which they were dried. The crazing which results from such treatment is caused by the crystallization of the salt beneath the surface of the glaze in the porous body. Since the amount of salt crystallizing determines the strain under the glaze it is evident that while this test gives a comparison of glaze fit on two bodies of the same porosity it would not give a fair comparison when the porosities differ. This test is of value to the potter who is testing plates of approximately the same porosity from time to time, but could not reasonably be used to compare for instance a semi-porcelain of eight per cent absorption and a vitrified ware.

A crazing test for tableware based on quenching the ware at temperatures of from 120°C to 200°C in water at room temperature was studied by Harkort.[3] The cause of crazing in such a test is primarily the difference in coefficient of expansion of body and glaze, and corresponds closely to the causes of crazing of ware in actual use. He found that ware which would withstand quenching from 190°C to room temperature was safe from crazing for two and a half years, the extent of his observations. In developing a test for crazing of wall tiles Pence[4] also suggests such a test, he having

[1] Stover, *Trans. Amer. Ceram. Soc.*, **11,** 89 (1909).

[2] Ashley, *Ibid.*, **9,** 59 (1907).

[3] Harkort, *Ibid.*, **15,** 368 (1913).

[4] Pence, *Ibid.*, **18,** 622 (1916).

found that quenching from 163 °C to 0 °C was a reasonable guarantee against crazing in that type of ware.

After preliminary experimenting at different temperatures it was decided that several immersions in the neighborhood of 180 °C would give a reliable indication of freedom from crazing in use including a margin of safety. Since it was found that the technical staff[1] of one of the larger potteries had reached a similar conclusion, the test adopted consisted in quenching five inch plates at 175 °C in tap water (15–20 °C) ten times. Ware which will stand this treatment without crazing may be safely relied on to stand up in service. Repeated immersion is to be desired in preference to a single immersion at a higher temperature since it minimizes variations which might enter from unequal heating.

Before quenching the plates were heated in an electric furnace from twenty minutes to half an hour to insure uniform temperature conditions as indicated by a thermometer at different places on the specimens. After ten immersions at 175°, the plates were quenched five times at 200°, five times at 225°, and five times at 250°. Quenching at these higher temperatures is a very severe test, far more rigorous than ordinary service, and was conducted simply to give a measure of the margin of safety present in the various wares.

The results given in Table II are averages on several five inch plates of each make, the number depending on the agreement of the results obtained. Variations were noted in different pieces of some brands but in most cases like pieces checked within one or two immersions. Owing to the fact that five inch plates of some brands were not available not all of the wares listed in Table I could be included in this test.

It was found that most of the vitreous bodies would not stand the sudden change at the higher temperatures as cracking of the plates would result. Ability to withstand moderate temperature changes is important because those wares which will not rupture in the greater thermal shock are less apt to weaken from the repeated scalding to which they are subjected in the dishwashing machines. Therefore, in addition to being a test for crazing, this treatment gives a measure of the ability of the wares to withstand sudden temperature changes.

Of the six brands of domestic hotel ware tested none crazed from quenching at 175°. One ware crazed on the third immersion at 200°, and one on the second at 225°. One brand cracked at 225°, and three at 250°. Two wares, No. 1, vitreous, and No. 11, semi-vitreous, stood the entire treatment without crazing or cracking.

The four brands of English hotel ware crazed easily, one on the second quenching at 175°, two on the third, and one on the seventh, and consequently would not pass specifications based on this test.

[1] Communication from A. V. Bleininger.

TABLE II

RESULTS OF CRAZING TEST

No.	Type	Immersion on which failure occurred																									
		175°										200°					225°					250°					
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
1	Hotel china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	O.K.
2	Hotel china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cracked	..			
5	Hotel china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cracked							
7	Hotel china	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed		..	..	..	..	..	..	..	..	..	×	Cracked		
8	Hotel china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed			×	Cracked				
11	Hotel china, semi-vitreous	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	O.K.
14	English hotel ware	..	..	..	..	..	..	..	..	×	Crazed																		
15	English hotel ware	..	..	×	Crazed																								
16	English hotel ware	..	×	Crazed																									
17	English hotel ware	..	..	×	Crazed																								
18	French hotel china	..	..	..	..	..	×	Cracked																					
19	German hotel china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cracked												
20	German hotel china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cracked							
21	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed								
22	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed														
23	Semi-vitreous china	..	..	×	Crazed																								
24	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed									
25	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	O.K.
26	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed				
27	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	×	Crazed														
28	Semi-vitreous china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	O.K.
30	Japanese china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cracked											
31	Japanese china	..	..	..	..	..	..	..	..	×	Cracked																		
32	French china	×	Completely shattered																										
33	French china	..	..	..	..	..	..	..	..	..	..	×	Cracked																
34	German china	..	..	..	..	×	Cracked																						
35	German china	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cracked											

Although no crazing developed in the French and German hotel wares included in the work they showed a greater tendency to rupture from sudden temperature change, the French ware failing on the fifth immersion at 175°, one German product on the third at 200° and the other on the third at 225°.

Of the eight semi-vitreous household wares tested only one failed to stand the treatment at 175°. No. 23 crazed consistently on the third immersion. Two brands crazed on the second and third quenchings at 200°, two at 225°, and one at 250°. Two semi-porcelains withstood the entire treatment without failure. One of these, No. 28, was made wholly from domestic materials and gives an encouraging indication of the possibility of their greater use.

Two interesting deviations from ordinary crazing were noted in some specimens of this type of ware. Some plates would appear to be crazed but close examination would show that the fracture was at the point where body and glaze meet and did not reach the surface to produce an open crack. After a short time these marks would disappear leaving no sign whatever that the crazing beneath the surface had occurred. When this phenomenon appeared it was usually noticed on the first and second immersions before normal crazing occurred.

The other unusual crazing was noted only at the highest temperatures used. When some specimens were taken from the furnace at 250° craze marks were plainly visible but on quenching the piece they would entirely disappear and could not be located by washing the plate with red ink. These observations would indicate that in this case the coefficient of expansion of the body in the temperature range below 250°C was greater than that of the glaze, and on heating to 250° the difference in expansion was sufficient to cause crazing. When the ware was chilled to room temperature the glaze came together again so that no crazing of practical importance was present.

No crazing appeared in the foreign chinas for household use but all were susceptible to sudden temperature changes. One of the Japanese wares cracked on the seventh quenching at 175° and the other on the fourth at 200°. The specimens of one of the best known brands of French china were completely shattered on the first immersion at 175°, while the other French ware cracked on the tenth immersion at the same temperature. One of the German products cracked on the fifth treatment at 175° and the other at the fourth at 200°.

The effect of the structure of these bodies on their ability to withstand sudden temperature changes is clearly evident, the porous wares withstanding quenching at 250° without failure, the vitrified but still granular American bodies not failing until 225° or 250° and the glassy French, German, and Japanese wares failing on treatment at 175° and 200°, one German ware, however, not failing until 225°.

A summary of the results of the crazing test shows that the domestic hotel wares included in the work were safe from crazing in service, and only failed from sudden temperature change at the highest temperatures employed. The English hotel wares crazed comparatively easily, while the French and German wares tested did not craze but cracked on quenching at 175°, 200° and 225°. With one exception the domestic semi-porcelains studied did not craze during ten quenchings at 175° but crazed at the higher temperatures, two, however, withstanding the entire treatment. The French, German, and Japanese household chinas ruptured on immersion at 175° and 200°.

Impact Tests

For the impact test a modification of the pendulum apparatus devised by Staley and Hromatko,[1] shown in Fig. 1, was used. The steel disc "a" weighed six ounces and was nine-sixteenths inches thick and one and three-quarters inches in maximum diameter. The edge was rounded at a radius of five-eighths inch. Into it was soldered the stiff wire arm "b" of such length that the distance between the center of the disc and the point of suspension was two feet. At the upper end of the arm was the scale "c" which consisted of a ninety degree segment of a sixteen inch circle calibrated in divisions of 0.025 foot pound energy of impact. The formulas used in calculating the relation of angular fall to energy of impact have been given by Staley and Hromatko.[2]

The pendulum and scale were supported by a heavy adjustable stand. The plates were seated against three one-eighth inch ball bearings equilaterally placed in a circle three and one-quarter inches in diameter in the ring "d" which was firmly fastened to a solid backing.

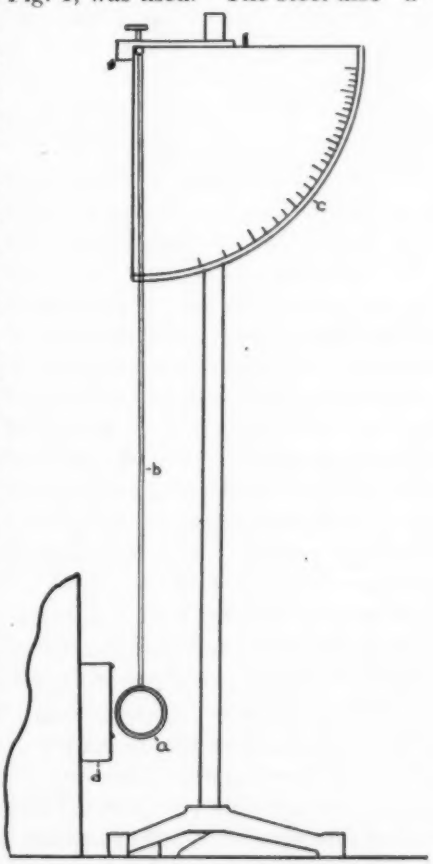


FIG. 1.—Apparatus used in impact tests.

[1] Staley and Hromatko, *Jour. Am. Ceram. Soc.*, **2**, 227 (1919).

[2] *Loc. cit.*

It was found that striking the plates in the center seated against the three balls gave more consistent results than striking them at one point on the foot with the outer edge seated against the bearing board, or by applying the blow at the center with the plates seated against a steel ring. The three points established a solid seating regardless of the warpage of the plates and afforded a firm base with none of the variations which might enter from cushioning the plate to overcome the effects of warping.

The fracture produced when plates are broken in this way usually occurs in lines radiating from the center of the plate. Complete fracture or cracks which weakened the piece sufficiently to be pulled apart by the hands were considered failure. Occasionally a hole was broken through the center, but this was usually due to defects in the structure of the plate.

While this fracture does not exactly duplicate that occurring when a plate breaks in falling, it was thought that the uniformity and consistency of the results obtained warranted its use for a comparative test.

In testing, a plate was held with the bottom resting lightly but solidly against the seat and was struck in the center. Ordinarily the first blow was 0.100 foot pound and each successive blow increased in intensity by 0.025 foot pound until failure occurred. In testing the wares that had a very low resistance to impact the first blow was 0.025 foot pound. These very light blows had no noticeable effect on the stronger wares.

The average results from the breaking of at least six plates of each kind are shown in Table I. Owing to lack of knowledge of the factors involved in the impact test it is impossible to derive mathematically the relation between the thickness of the plates and their ability to withstand impact. On this account the impact energy computed into units per unit thickness can not fairly be used for comparison of wares of different thickness and is consequently not given in the results. It is believed that this relation will be established empirically in the near future by the correlation of data from tests of ware made for the purpose, in which thickness is the only variable. The thickness of the plates is given solely for comparison.

With two exceptions the thirteen brands of American hotel ware required an average blow of from 0.200 to 0.400 foot pound to cause fracture. One ware, No. 5, a light weight hotel ware, broke at 0.175 foot pound and No. 9 fractured at 0.150 foot pound. The strongest ware tested was No. 10 which had an absorption of 1.4 per cent and required a blow of 0.400 foot pound to cause failure. The three semi-vitreous wares, Nos. 11, 12, and 13 compared favorably with the vitrified products.

The four English brands were not as strong as the American wares and failed at 0.125, 0.150, 0.150, and 0.175 foot pound, while the French and German wares tested were brittle and fractured at 0.100, and 0.125 foot pound, respectively.

The results obtained on the hotel wares are shown graphically in Fig. 2, giving both the blow to cause fracture and the thickness of the ware, which shows clearly that in regard to ability to withstand blows as indicated by these tests the American wares are much superior to the French, English, and German wares tested.

The eight brands of semi-vitreous ware for household use required an average impact energy of from 0.175 to 0.200 foot pound to cause failure while the one vitreous American ware broke at 0.225 foot pound. No. 28, the semi-porcelain made entirely from domestic materials, compared favorably with the others of that type.

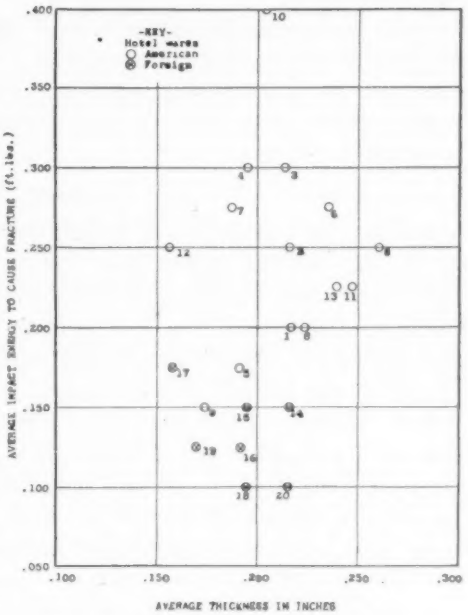


FIG. 2.—Results of impact tests on hotel wares.

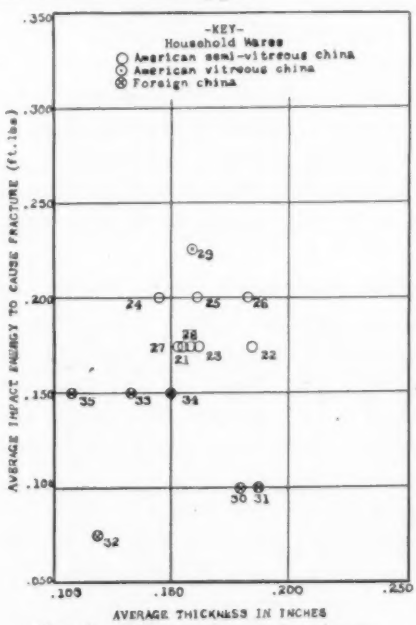


FIG. 3.—Results of impact tests on household wares.

The French, German, and Japanese household wares were brittle. One thin French ware failed at 0.075 foot pound and the heavier French ware at 0.150 foot pound. Both German brands failed at an average blow of 0.150 foot pound, and the two Japanese products at 0.100.

Fig. 3 shows graphically the results on household wares and indicates that the domestic wares will stand greater sudden blows than the imported chinas tested.

A comparison of glazed and unglazed pieces of several wares was obtained. No difference could be discerned. Possibly a more delicate test might show the effect of the glaze on the resistance to impact.

The effect of the structure of the

body on the properties of the ware is again shown. The comparatively granular domestic vitrified wares had a relatively high resistance to impact whereas the impervious, glassy, imported wares were correspondingly brittle with a lower ability to withstand blows.

Chipping Test

The test for clipping used in this work was essentially an impact test applied at the edge of the plate. The same device was used as in the impact test with the exception that the tup was a rectangular block of hardened steel one and one-half by one and one-quarter by one-half inches with the striking edge rounded at a radius of one-quarter inch. Its weight was six ounces so that the same length arm and the same scale for impact energy could be used. The plates were seated horizontally on a heavy stationary iron slab on which were bolted two steel bars forming an angle of ninety degrees, and were struck at the point on the edge so that the blow was absorbed equally at the two points of contact of the edge with the bars. Since its use by the Bureau this general method has been adopted in at least one of the potteries as shown by the paper by Schramm.[1]

In testing, the same procedure was followed as in the impact test, the plate being struck with a blow of 0.100 foot pound, each successive blow being greater by 0.025 foot pound, until a chip appeared. The plates were chipped at four different points after it was found that previous chips had no apparent effect on the results at other points. Only the hotel wares were given this test.

The results obtained were not as consistent as might be desired as different points on the same plate in some cases varied as much as different plates of the same set, but the average results obtained showed considerable variations between different brands. The results given in the last column of Table I are averages for a minimum of twelve chips on at least three different plates of each make.

Comparison of these results with those obtained from the impact test shows that there was no direct relation between them. This may be attributed in large part to the influence of the design of the edge and the angle of inclination of the rim. In fact, it is shown by the data that plates of equal or similar body properties, but of different edge design differed so widely as to justify the conclusion that the latter factor had as great an effect on chipping as the inherent properties of the body.

The average energy to cause chipping varied from 0.100 to 0.400 foot pound. In some cases the energy required to produce a chip was greater than that required to fracture the plate when struck in the center. The majority of the wares required a good hard blow to produce a chip.

[1] Schramm, *Jour. Am. Ceram. Soc.*, **5**, 136 (1922).

Some wares, Nos. 5, 9, 11, 12, 17, 18 and 20, were more prone to chipping as indicated by lower results, and the cause could usually be ascertained by examination of the chipped plates. The low value for No. 5 was due to the thinness of the edge and the low angle of inclination of the rim which was almost horizontal. No. 9 was brittle as shown by its giving the lowest results in the impact test, of the American wares tested. The early failure of No. 11 was in part due to the fact that the striking edge of the plate received the blow in such a way that a chip was sheared off instead of transmitting the blow uniformly to the body of the piece. No. 12 failed for the same reason, and the result on No. 17 can be partly attributed to this factor. The French ware, No. 18, was the most brittle hotel ware tested and consequently gave a low value for chipping. Its design was also conducive to this. No. 20 also failed at a blow comparative to its low resistance to impact.

Owing to the fact that plates with similarly designed edges were not available no conclusive evidence as to the comparison in resistance to chipping of the American vitreous and semi-vitreous hotel wares was obtained.

The domestic wares gave good results with the exceptions of those affected by poor design. One of the English wares gave a high value, two were fair, and one poor. The French china chipped very easily, and one German ware gave next to the highest result obtained while the other resembled the French ware.

The results show the great importance of the design of the rolled edge on the ability of the ware to withstand blows at the edge. An investigation of interest and importance to the potters making hotel ware would be the testing of a large number of plates of all the different designs in use made by one workman from one body and fired in the same kiln, to determine the designs giving the greatest resistance.

Resistance to Alkaline Solutions

In use the glaze on tableware is subjected to hot, dilute, alkaline dishwashing solutions, while the acids with which it comes in contact are weak, usually dilute, and are at moderate temperatures. In order to determine the effect of such solutions as are used in dishwashing machines, plates of each make were boiled six hours in a half normal ($3^1/_2$ oz. per gallon) solution of sodium carbonate, and six hours in an approximately 4 N (27 oz. per gallon) solution. No effect of this treatment could be noticed.

It was thought that the effect of the dishwashing solutions might take place after the surface of the glaze had become marred by cutlery marking and abrasion. Plates of several representative makes of each type of ware were accordingly scratched with a diamond point so that the solution

could come in contact with the glaze beneath the glossy surface. Two plates of each kind were scratched, one for treatment and one to be kept for comparison.

The plates were then boiled in a half normal solution of sodium carbonate, and examined at intervals to note any effects of the treatment. At the end of twenty-five hours' boiling the plates were removed, thoroughly rinsed in hot water, and examined. No effects of the solution were visible on any of the plates. Microscopic examination at a magnification of 250 failed to show any difference between the plates treated and those kept for comparison.

These results indicate that the glazes now in use on tableware are capable of withstanding alkaline dishwashing solutions over a long period of time.

An important test to be developed is one that will give a measure of the resistance of the glaze to cutlery marking and abrasion. While some experiments have been made in this direction no entirely satisfactory results have been reached at this time.

The author wishes to thank those potters who have shown their interest in the work by contributing ware for the investigation.

BUREAU OF STANDARDS
WASHINGTON, D. C.

NOTES ON DIAGNOSING CAUSES OF CORDS IN GLASS

By F. Twyman[1]

ABSTRACT

The physical properties, *e. g.*, refractivity, viscosity, and expansion coefficient, of cords generally differ from those of the mass of the glass. Methods are described for rapidly ascertaining the relative values of these properties. This information, together with a knowledge of the batch ingredients and possible impurities may afford in certain cases a means of determining the cause of the cords.

A great deal of information may often be obtained very rapidly by using the following methods of examination:—

1.—Are the cords of higher or lower refractive index than the mass of the glass?

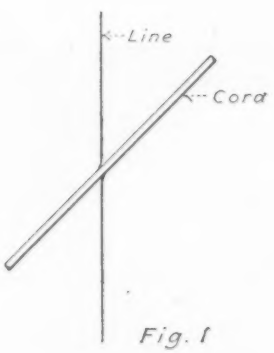


Fig. 1

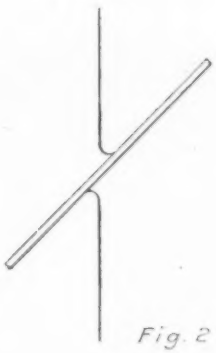


Fig. 2

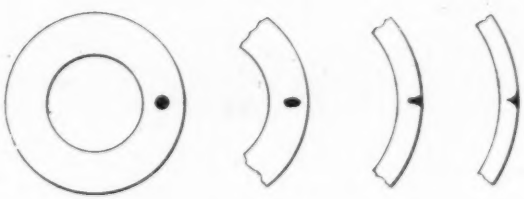


Fig. 3

A straight line, such as a window blind cord or line drawn on paper, is observed through the glass under examination in such a way that the line is intersected obliquely by the cord. The line should not be too far away, nor the glass too near the eye, in order that both should appear simultaneously in focus. A cord of high refractive index would then cause distortion as in Figure 1, and one of low refractive index as in Figure 2. It is obvious that precisely the same effect would be caused by a

[1] Published by kind permission of Messrs. British Glass Industries Ltd., to whom the author's thanks are due.

streak irregularity in the surface—a ridge in the first case and a depression in the second; and some such irregularity is nearly always present in the cords which occur in practice.

In all but the most extreme cases, however, the refractive index effect would outweigh that due to irregularity of surface. Immersion in a homogeneous liquid of suitable refractive index would in any case eliminate this source of error.

2.—Is the cord of higher or lower viscosity than the remainder of the mass?

If a cross-section is taken along the cord, and its direction noted, particularly whether it emerges from the glass surface (as it frequently does), one can generally state whether the cord was of higher or lower viscosity than the remainder of the glass when moulding occurred.

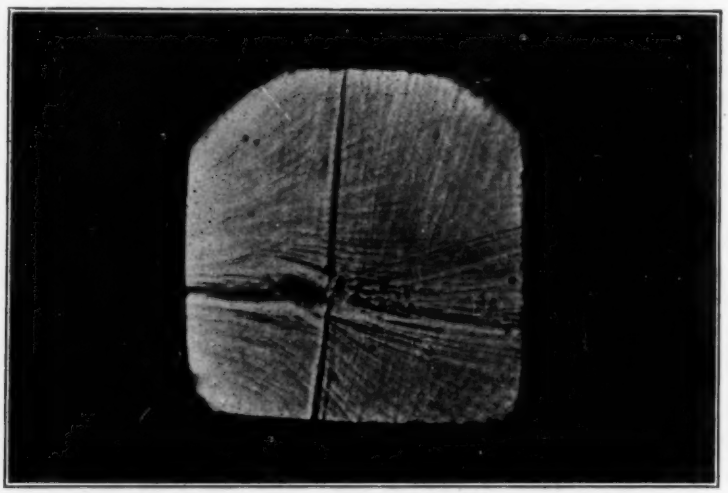
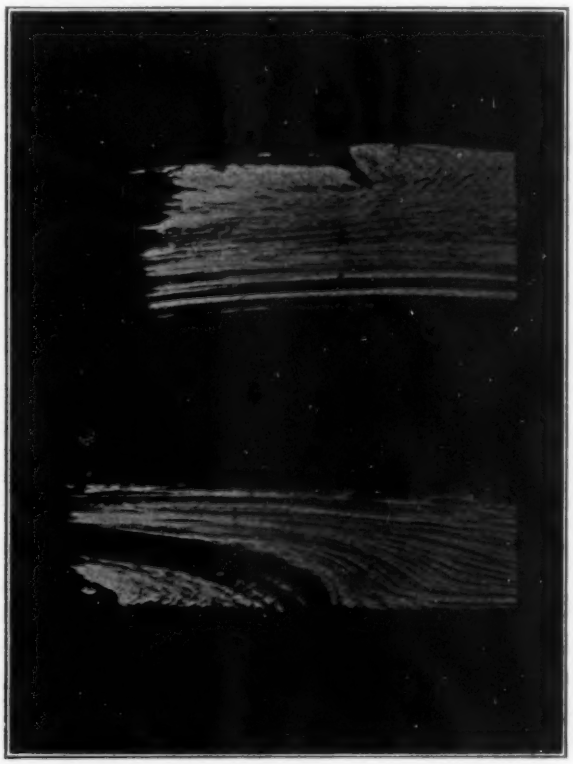


FIG. 4.

In the diagram (Fig. 3) the left hand figure represents the cross-section of a gathering in process of blowing, and the black dot is a cord. Then the cord will flow outward in a more or less stream-like manner, finding an outlet at the free surface, as indicated by the successive figure to the right, and if of lower viscosity it will at the surface flow over the remainder of the glass. If it is of higher viscosity this will not occur, but the remainder of the glass will flow over it.

This effect may be further illustrated by the photographs reproduced. Figure 4 is a low power photomicrograph of a portion of the side of a bottle, viewed through the side in the ordinary way, but with the surfaces ground and polished. Two cords are seen crossing at right angles, one clear and

distinct, the other rather diffuse. The former was due to a fold in the glass, the latter to a cord such as I have described. Cross-sections of each of these cords were cut by planes perpendicular to the plane of the paper. These were polished and photographed. That of the vertical cord (Fig. 5) which the original sample showed clearly as a fold, is not quite so convincing in the photograph. The other cord, however, shows in cross-section (Fig. 6) a decided streaming outwards, and it should be noted that a streak of severe double refraction was present in the glass which coincides with the stream, and which could not be removed by annealing.



FIGS. 5 AND 6.

3.—Had the glass in the neighborhood of the annealing temperature a higher or lower coefficient of expansion?

If by observation in polarised light the direction of strain is noted within the cord, namely, whether it is compression or extension, one can immediately say whether the coefficient of expansion of the substance of the cord was higher or lower than that of the mass of the glass.

4.—Occasionally devitrification occurs within the cord. If this is the case, it indicates a high probability that the cord is more liable to devitrification than the remainder.

Generally speaking, cords are not the result of devitrification of a portion of the glass of the same composition as the mass. On the contrary, in those cases when devitrification is present within the cords, the glass forming the cord has been contaminated in such a way, for example, by excessive lime content, as to give rise to devitrification.

All cords examined by the writer have had physical properties differentiating them in a marked degree from the mass of the glass. It does not appear that cords can occur in a homogeneous melt, even though, in the process of gathering and moulding, extreme differences of temperature and consequently of viscosity, have been temporarily introduced. There is, indeed, an action which tends to rapidly efface such differences of temperature. Those regions which are hotter are, of course, less viscous, and in the blowing rapidly become thinner than the remainder. Once thinner, radiation soon renders them cooler than the remainder; and it is then the latter which begins to get thin more rapidly. Briefly, then, so long as one portion of the article is thicker than the rest, it remains hotter, and hence gets thin more rapidly; while so long as one portion is thinner than the remainder it soon gets cooler, and therefore gets thin more slowly. There is thus a powerful influence at work, tending towards uniformity alike of thickness and temperature. Folds of course do occur owing, probably, to a very sudden chilling of that portion of the glass which touches the mould first.

Contamination may easily occur through the careless introduction into the furnace of some substance of low surface tension, followed immediately by such a substance as will float, and, by dissolving, cause cords—lime, for instance—which will be carried rapidly across the surface in an undissolved state, unless an effective surface baffle is employed, thus increasing locally the lime content. Or the impurity (*e. g.*, lime) may by its own solution, cause variations of surface tension, causing it to travel across the surface.

If, then, the co-relation between

(*a*) refractive index,
(*b*) viscosity,
(*c*) coefficient of expansion,
(*d*) liability to devitrification,

and the various constituents or impurities of the glass are known, a very rapid diagnosis may be made in many cases, and may immediately fix the cause of the cords.

THE RESEARCH DEPARTMENT
ADAM HILGER LTD.

Discussion

BY G. W. MOREY:—Careful study of the imperfections in glass may be made to yield information of great value to the glassmaker, and often may suggest a modification of procedure which will eliminate the cause of the imperfection. The determination of the relative refractive index by the method suggested, which is essentially that already described by Wright,[1] is of especial value in ascertaining the source and cause of cords and striae and has many times proven serviceable to me. It is surprising how prominent a cord appears whose difference in refractive index from the surrounding glass is only one point in the third decimal place, and this amount is generally sufficient to enable one to ascertain which of the two has the higher refractive index, especially if the glass be immersed in a liquid of approximately the same refractive index. In the writer's experience, cords of higher refractive index than the glass are of rare occurrence, and have been caused by insufficient mixing of the melt.

It is correct to state that if the cord has a different coefficient of expansion than the glass, strain will result, but this is caused by the difference of expansion coefficient not only in the neighborhood of the annealing range but also, and more particularly, below the annealing range. Indeed, such glass might be cooled throughout its annealing range in such a manner that no strain appeared, but when cold, strain would be present.

It is of course conceivable that devitrification might take place within the cord, but, as a rule, when crystalline material is found in cords, it is more probable that the crystalline material itself is the cause of the cord. The optical identification of the crystalline material as described by Bowen[2] is of the greatest value in locating the source of cords caused in this manner.

[1] Wright, *Jour. Am. Ceram. Soc.*, **4**, 655–661 (1921).

[2] *Ibid.*, **1**, 594–605 (1918).

DERRY FELDSPAR QUARRY[1]

By N. B. Davis

ABSTRACT

An outstanding development in feldspar at Buckingham, Quebec, where a large deposit of high-grade potash feldspar known as Derry Quarry has been opened up and placed on a shipping basis.

Introduction

For a considerable number of years the country north of Buckingham, Quebec, along the Lièvre River, has produced small tonnages of the highest grade feldspar known, and supplied to the dental trade. This feldspar was usually secured when mining for white mica, and from deposits of very limited size.

Early in 1920 an attempt was made to work one of these small deposits for material suitable for porcelain manufacture but it was found impossible to make ends meet. This lead to prospecting new ground with the idea of discovering a large body, and in September work was started on the outcrop of what may now be described as the largest body of clean straight feldspar known on the continent.

In the various spar districts there appears to be but one deposit of outstanding merit surrounded by a number of small bodies subject to greater variation. This also seems to be the condition in the Buckingham district.

Location

The Derry Quarry is located in the hills above the Lièvre River valley near Glen Almond some nine miles north of the town of Buckingham, and about thirty miles from Ottawa. It is accessible by a good motor road, or by steamer within two miles in summer, and by sleigh in winter.

Geology

The deposit is part of a large intrusive mass of pegmatite that can be traced across country for a mile or more with the greatest development of crystallization on the south half of lot 8, range 1, of the township of Derry. On the south end of this lot the pegmatite has a width of one hundred and fifty feet, and differentiation of spar has taken place on a huge scale. The outcrop shows a width of 50 feet and a length of 300 feet of clean spar crystals, individuals attaining dimensions of 30 feet in length and up to 15 feet diameter.

A cross section of the deposit is somewhat as shown in Figure 1.

Quartz is present in very subordinate amount, approximately 1.5% by actual tonnages separated, a most remarkable record when compared with the general run of such dikes.

[1] Received March 25, 1922.

Accessory minerals, such as tourmaline and mica, are present only in small amounts near the walls and can be easily separated in the mining operation.

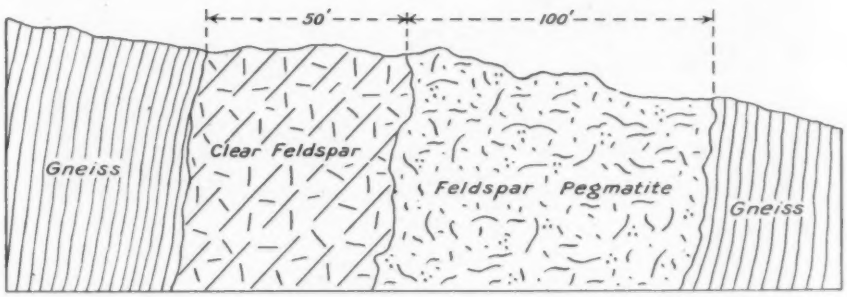


Figure I. Cross section of Derry Feldspar Quarry, Buckingham, Quebec

The feldspar is cream to buff colored and typical analyses of the grade of material shipped are as follows:

	A	B
Silica	65.09	65.80
Alumina	18.85	19.74
Iron	0.029	0.031
Lime	0.21	0.11
Potash	13.42	12.32
Soda	2.11	1.74

(Analyses by Booth, Garrett & Blair, Philadelphia)

Quarry Operation

The present opening is in the form of a side hill cut and with a working face 50 feet high no hoisting will be necessary for a year or more.

Great pains are taken to maintain the original purity of the material. The surface six feet are quarried separate to ensure minimum contamination from seepages. The central 30–40 feet are blasted and mucked out before the wall zones are touched.

Holes are drilled across the face to depths of 8–14 feet and two to three benches carried forward. Each hole is sprung to take the necessary charge of dynamite.

In the pit each man uses a stone fork (no shovels) and as the spar is loaded on flat cars two inspectors watch it for the elimination of any objectionable material that may get past the muckers. The cars are dumped into a 100 ton storage bin to pass by gravity to the wagons or sleighs as required.

In the summer wagons take the material to the river bank where it is dumped into another loading bin and to a 40 ton scow to be transported

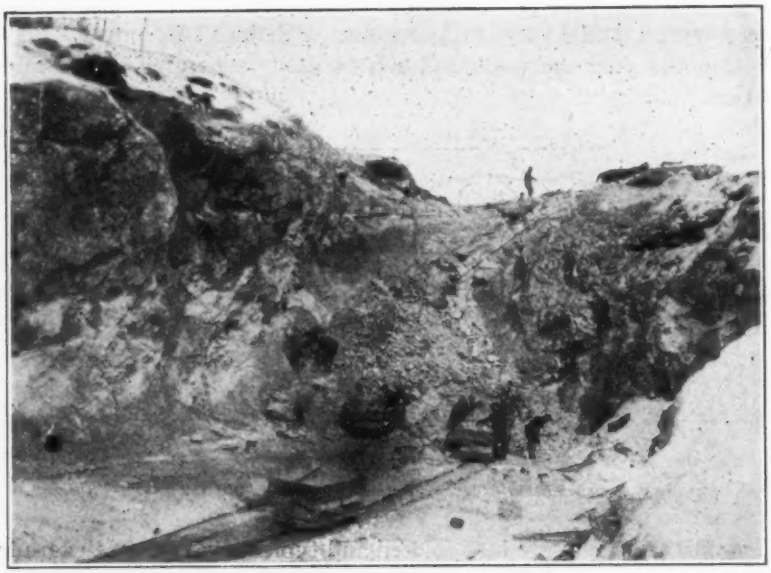


FIG. 2.—Face of quarry, 1921-22.

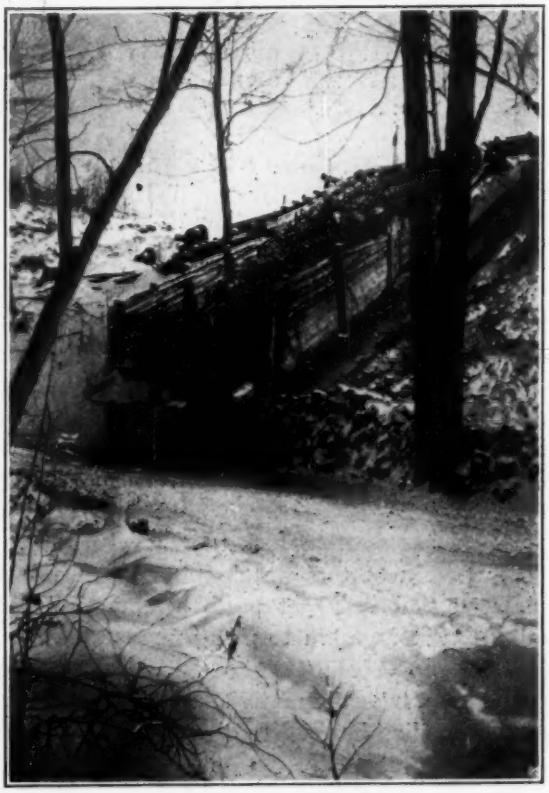


FIG. 3.—Ore bin at mine.

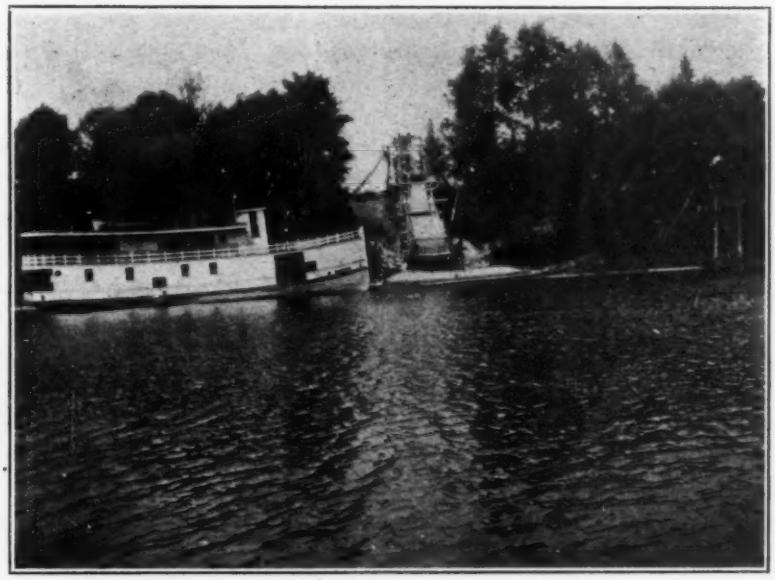


FIG. 4.—Summer transportation on Lièvre River.

FIG. 5.—Winter transportation.

down stream to the railroad siding at Buckingham. Here a suitable derrick is provided for loading the railroad cars or placing in stock pile. The piling ground is covered with a plank platform so that from the time the feldspar is loaded out from the quarry to the time it is shipped every effort is made to keep it scrupulously clean.

The fine material or waste material from the quarry finds a ready market as a stucco dash giving a rich cream to buff tone to a building. The quartz is sold locally for use as a flux in the electric furnace manufacture of phosphorus and its compounds.

Hence the Derry quarry stands unique in having an abundance of the highest grade feldspar, a minimum of accessory minerals, and no waste material.

O'Brien and Fowler
Ottawa, Canada

SOME EXPERIMENTS ON THE FIRECRACKING OF TERRA COTTA[1]

By E. C. Hill

ABSTRACT

Firecracking occurs on terra cotta under certain conditions and is characterized by the appearance of sharp, hair-line cracks extending into the body. The experiments were made by firing large typical pieces of terra cotta made from various clays and grogs and cooling them at different rates. The tendency to firecrack was observed after weathering. The absorption, porosity and transverse strength of the various bodies were determined.

Rate of Cooling.—All bodies similar to those used in practice showed a tendency to firecrack when cooled rapidly and all were free from cracks when cooled slowly. The rate of cooling has a much greater effect on the tendency to firecrack than the composition or physical properties of the body.

Effect of Clay.—Three of the four sandy clays showed a decided tendency to firecrack, due to the difference in the expansion and contraction behavior of sand and clay in heating and cooling. The sandy clays showed more tendency to firecrack than the non-sandy, vitrifying clays. The tendency of a clay to develop firecracks in a body depends to a very large extent upon the character of the clay itself, regardless of the impurities it contains. The presence of sandy material and the character of the clay appear to have a much greater effect on the tendency to firecrack than the absorption, porosity or transverse strength of the body. No relation was found to exist in these experiments between the porosity and transverse strength of a body and its tendency to firecrack.

Effect of Grog.—The greatest tendency to firecrack was found on a body with all grog finer than 40-mesh, but a body with all grog coarser than 40-mesh did not appear to have much less tendency to firecrack than the average. Increase of grog reduced the tendency to firecrack. The kind or source of the grog used does not have as much effect on the tendency to firecrack as the size and amount. The kind of grog is of much less importance in this respect than the kind of clay.

Introduction

Definition of Firecracks.—The sharp, hair-line cracks that may appear on terra cotta under certain conditions are termed firecracks, cooling cracks or dunting. They are caused by contraction strains being set up in the body during the cooling. If these strains are severe the piece may be cracked when drawn from the kiln. If the strains are less severe, the cracking may not occur until a considerable time after the piece has been set in the building.

Firecracks Due to Strains.—Pieces set in the wall generally do not develop firecracks so readily as those placed in projecting courses and in exposed positions. When placed so that they catch the direct rays of the sun, they are subjected to an unequal heating nearly every day, with a subsequent cooling at night. If such pieces have had severe strains set up in them during the cooling of the kiln, they are likely to develop firecracks.

[1] Read before the Terra Cotta Division, St. Louis meeting, February 28, 1922.

In some experiments made six years ago, some pieces were placed on the roof where they would be exposed to the weather. There were no failures whatever until during the third year, when a considerable number of the trials developed firecracks. It is possible, however, that even when cooled slowly, pieces may be of such size and shape and the body of such composition that they would be unable to withstand repeated expansion and contraction strains over long periods of time in service.

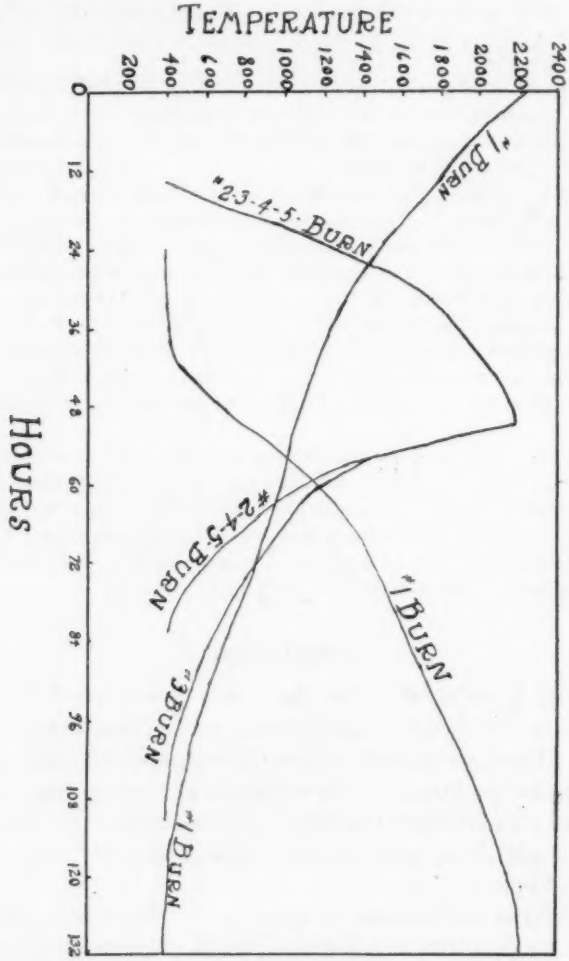


FIG. 1.

Too Rapid Cooling a Cause of Firecracking.—It is generally recognized that firecracking is due to too rapid cooling of the kilns and the customary procedure is to lengthen the cooling period. In periodic kilns, there is a considerable difference in the rate of cooling in different parts of

the kiln. In firing terra cotta, where there is such a variety of sizes and shapes, the cooling period must be long enough to cool the largest pieces in the parts of the kiln where the cooling is the most rapid. The kilns used at the different plants vary in size from capacities of 15 to 100 tons so that if the cooling is not regulated, the time of cooling often varies 100%. There is no general practice regarding a safe cooling period and in practice it may be from 4 to 8 days.

While the effect of the rate of cooling on the tendency of bodies to firecrack is generally understood, there is a wide difference of opinion in regard to the effect of the composition and physical properties of the body. The experiments reported in this paper were made in an attempt to obtain some data on the effect of the composition and physical properties of the body, and to determine the relative importance of the composition, physical properties and rate of cooling.

Investigation

Methods.—The trials for firecracking were made in the form of pieces of a dentil molded course 24″ long, 10″ wide and 14″ deep, weighing about 115 lbs. Three trials of each body were fired in each burn, two being glazed and one coated with a vitrified slip. The bodies were prepared by grinding the clay and grog separately to pass a 16-mesh screen. One per cent barium carbonate was added to the clay. The clay and grog were mixed dry on the floor by hand-shoveling and pugged in a small pug mill. The pieces were pressed in the usual manner.

The trials for linear fire shrinkage were 7″ x $3\frac{1}{2}$″ x 2″ and the results given are the average of five.

The transverse strength trials were 8″ x $1\frac{1}{4}$″ x 1″ and the results given are the average of ten. These were broken on an Olsen Shot Transverse Strength Machine with a 6-inch span and the modulus of rupture calculated by the usual formula.

The absorption trials were about 2″ long and were obtained from the broken transverse strength trials. They were boiled in water for 2 hrs. and the absorption calculated by the usual formula. The porosity determinations were calculated by the Purdy formula.

Series I

Six bodies of widely different composition were used. All have two parts clay to one of grog. No. 1 is made of Campbell Red (N. J.) clay, which vitrifies at Cone 6 and vitrified porcelain (sanitary ware) grog. No. 2 is a mixture of terra cotta clays and the same grog. No. 3 has the same clay as No. 2 but has porous sagger grog. No. 4 is composed of a very sandy local clay, No. 5 Tennessee Ball clay, and No. 6 Georgia kaolin.

These bodies were fired to Cone 6 in three different burns. Burn No. 1 was made in a 40-ton terra cotta kiln with the regular ware and represents an average burn. The trials for shrinkage, absorption, etc., were fired in this burn and the results given in Table I.

Burn No. 2 was made in a test kiln of one and a half tons capacity. The cooling is regulated by the damper in the stack. The kiln was cooled as quickly as possible by opening the damper in the stack, drawing air through the fire holes and up around the muffle and out the stack, but without any direct opening into the muffle. The curves shown on the chart are the average of several made in these experiments, the first curve obtained being followed as closely as possible. A duplicate set of shrinkage, absorption, etc., trials were fired in this burn and the results were reasonably close to the No. 1 burn.

Burn No. 3 was made in the same kiln in the same manner as No. 2, except that, in cooling, when 1200°F was reached the damper in the stack was closed and the fire holes shut, so that the balance of the cooling would be at as slow a rate as possible with this kiln.

Results

SERIES I

CLAYS

No.		Per cent linear fire shrinkage	Per cent absorption	Per cent porosity	Modulus rupture no. sq. in.
1	Campbell Red	8.45	.42	.96	4422
2–3	Terra Cotta Mix	6.31	7.78	15.79	3362
4	Penna. Sandy	7.62	6.77	14.34	2002
5	Tennessee Ball	10.50	4.82	10.87	3610
6	Georgia Kaolin	7.91	15.79	27.34	1628
	BODIES				
1	Campbell Red-Vit. Porc	5.71	4.79	10.19	2876
2	Terra Cotta-Vit. Porc	4.43	10.33	20.43	2310
3	Terra Cotta-Sagger	2.51	14.90	27.56	1573
4	Penna. Sandy-Sagger	3.53	13.08	25.10	1350
5	Tennessee Ball-Sagger	5.34	13.62	26.00	1980
6	Georgia Kaolin-Sagger	3.22	18.47	32.91	1757

The trials for firecracking have been on a roof exposed to the weather for one year.

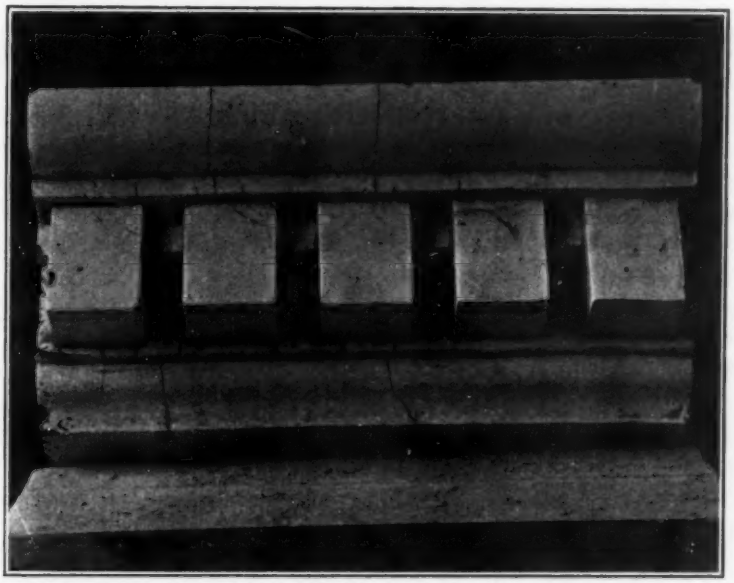
1. Campbell Red-vitrified porcelain. Burn No. 1, all O. K. Burn No. 2, one of three trials has two deep cracks. Burn No. 3, all O. K. Faint, fine-mesh crazing in wavy lines is starting to develop on some glaze trials in burns No. 2 and 3.

2. Terra Cotta mix-vitrified porcelain. Burn No. 1, O. K. Burn No. 2, all cracked. Burn No. 3, all cracked but less than burn No. 2.

3. Terra Cotta mix-sagger grog. Burn No. 1, O. K. Burn No. 2, all cracked. Burn No. 3, all cracked but less than burn No. 2.

4. Penna. Sandy clay-sagger grog. Burn No. 1, both glaze and slip are crazed. One of three trials cracked. Burn No. 2, all badly cracked and glazed trials badly crazed. Burn No. 3, all badly cracked and glazed trials badly crazed.

5. Tennessee Ball clay-sagger grog. The unglazed trial has several shrinkage cracks in wavy lines that extend into the body a short distance, but no sharp hair-line cracks characteristic of firecracks. The glazed trials are crazed and have a few slight shrinkage cracks, but no firecracks. In



Photograph showing typical firecracking in these experiments.

burns No. 2 and No. 3, the rapid firing has increased the shrinkage cracks greatly, so that the pieces are probably no stronger than if firecracked. The development of shrinkage cracks that extend deep into the body have probably prevented firecracks from developing. The glazed trials are badly crazed.

6. Georgia kaolin-sagger grog. Burn No. 1, unglazed trial has a few slight shrinkage cracks. The glazed trials have no cracks of any kind, but one trial has severe shivering of the glaze. Burn No. 2, the trials have slight shrinkage cracks, but no firecracks. Burn No. 3, no firecracks. The unglazed trial has slight shrinkage cracks, but both glaze trials have none.

In firing the trials in the large kiln (burn No. 1) all the pieces were set against the muffle in the same part of the kiln, so that all received about the same treatment in heating and cooling. In the small kiln, burns Nos. 2 and 3, the pieces received about the same treatment in heating, but the cooling treatment, no doubt, varied considerably, depending upon their position in the kiln. Pieces of the same body were separated as much as possible so that the average treatment of the three trials were about the same.

All bodies were free from firecracking in burn No. 1, except one trial of the Penna. Sandy clay body. There was less cracking in the No. 3 burn than the No. 2 burn, but in only one case, that of the one trial of Campbell Red body, was the additional time of cooling sufficient to overcome the cracking.

The body showing the greatest tendency to firecrack was the Penna. Sandy clay body. After weathering a month, body No. 2, Terra Cotta mix-vitrified porcelain grog, had developed more cracks than No. 3, with the same clay and sagger grog, but after one year's weathering the difference is not so marked. For burn No. 3, the trials show about the same amount of cracks, but for burn No. 2, body No. 3 has less cracking. Body No. 1, with the vitrified Campbell Red clay and vitrified grog, has less cracking than any except the Georgia kaolin body. The Tennessee Ball clay body can hardly be considered in these comparisons on account of the severe shrinkage cracks developed.

Penna. Sandy clay body caused the greatest crazing in the glaze. The Tennessee Ball clay body also has severe crazing. Faint crazing has started on the Campbell Red clay body. The crazing is greater in all cases in the short burn with rapid cooling. One trial of the Georgia kaolin body shivered in the long burn, but no further shivering has developed on the other trials. This trial was shivered when drawn from the kiln. It should be noted that crazing occurs on the very plastic Tennessee Ball clay body and on the very sandy Penna. Sandy clay body, while shivering occurs on the porous Georgia kaolin body. Until further data are obtained on the effect of the body on the crazing and shivering behavior of this type of glaze (Bristol), the effect of the different kinds of clay in the body can not be predicted from the composition or physical properties.

Aside from the fact that practically all the bodies are free from firecracking when cooled as in burn No. 1 and all of the bodies similar to those used in practice firecracked when cool as in burns Nos. 2 and 3, no further information has been obtained in regard to the rate of cooling. In burn No. 2, it required 33 hrs. to cool to 400°F, and would probably require 12 hrs. more to cool down to the temperature at which the door is usually taken down, and air allowed to enter directly into the kiln, making a total cooling period of 45 hrs. In planning these experiments, it was thought that by cooling more slowly below 1200°F, some bodies might be

cooled safely in this way, but no great difference was found between the two burns. It required 60 hrs. to cool to 400°F in burn No. 3, and with an additional 12 hrs. for cooling to the temperature at which the door could be taken down, would make a total of 72 hrs. In another burn, by closing the damper in the stack shortly after the firing was stopped, the cooling was prolonged 12 hrs., making a total of 84 hrs. Trials made from a body similar to the No. 3 developed firecracks in this burn. This burn gave the slowest rate of cooling possible in this kiln, without continuing the firing during the cooling period, which, no doubt, would produce very uneven temperatures inside the kiln. For this reason it was impossible to continue the experiments on the rate of cooling.

Burn No. 1 represents a typical firing and cooling curve for a 40-ton kiln with the thermo-couple at the muffle wall half-way up the kiln. The firing requires from 132 to 144 hrs. In the burn shown by the curve, the door was taken down after 168 hrs. (7 days). This represents a standard cooling period of $6^1/_2$ to 7 days. When stressed for time, the kilns have been cooled in $5^1/_2$ to 6 days without danger of firecracking as far as we can determine. When cooled in from $4^1/_2$ to 5 days, firecracking has developed in the past on large pieces after weathering for a considerable period, and to guard against this we have increased the standard cooling period to $6^1/_2$ or 7 days. In presenting this cooling curve, it must be borne in mind that the bottoms of these kilns cooled at a considerably greater rate than at the point where the temperature is recorded.

Experiments could be made with profit in shortening the time of cooling as shown by the curve for the No. 1 burn. The cooling could likely be more rapid for temperatures above 1200°F. The difficulty in shortening the cooling period comes from the fact that it requires such a long period of weathering to determine whether or not we are damaging the ware.

Series II

These experiments were made in the same manner as Series I, using 7 terra cotta clays and factory grog. Two parts of clay to one of grog were used. The bodies were fired to Cone 6 (burn No. 4) in the test kiln and cooled rapidly. The trials for absorption, strength, etc., were fired in a large kiln, similar to burn No. 1 in order to conform to the Series I trials. The trials for firecracking have been weathered nine months.

There is no crazing or shivering on any of the trials and no shrinkage cracks (wavy lines).

All trials are firecracked. Enterprise No. 30 developed considerably more cracks than the others. Russell Black clay has less cracks than the Enterprise but more than the remainder. The remaining five bodies are so nearly alike that no distinction can be drawn between them, except that the body with McDowell Buff clay has a trifle more cracks than the others.

Results

Series II

Clays

Body	Clay	Per cent residue 200-mesh	Per cent dry shrinkage	Per cent fire shrinkage	Per cent absorption	Per cent porosity	Modulus rupture lbs. per sq. in.
7	Crossley No. 1—N. J.....	8.20	6.16	6.68	9.45	19.27	3226
8	Enterprise No. 30—N. J...	7.09	5.93	5.48	8.96	17.87	3095
9	Edgars No. 9—N. J.....	.14	3.99	7.49	.09	.20	6130
10	Cursey Buff—Md.....	1.12	5.78	7.26	1.02	2.12	4784
11	Cursey Blue—Md.....	2.57	6.79	7.65	2.83	6.51	4701
12	McDowell Buff—Md.....	1.16	5.73	7.98	.41	.61	6385
13	Russell Black—Md.....	15.10	5.21	5.71	4.64	9.90	2882

Bodies

Body	Clay	Dry mod. rupture lbs. per sq. in.	Per cent fire shrinkage	Per cent absorption	Per cent porosity	Modulus rupture lbs. per sq. in.
7	Crossley No. 1—N. J.....	151	2.77	16.14	29.65	1665
8	Enterprise No. 30—N. J.....	117	2.53	15.62	28.91	1568
9	Edgar No. 9—N. J.....	100	4.21	12.21	23.49	2287
10	Cursey Buff—Md.....	158	3.87	11.19	21.99	2437
11	Cursey Blue—Md.....	202	3.10	13.94	25.95	2004
12	McDowell Buff—Md.....	154	4.03	11.06	21.53	2365
13	Russell Black—Md.....	...	2.46	12.28	23.73	1860

All of the clays in this series, except the Russell clay, have been in use during the past two years, and some of their physical properties determined from different shipments. While the residue when washed on a 200-mesh screen can not be used as a value indicating the sandy nature of the clay, since the residue may contain other impurities and sand finer than 200-mesh, it does show to a limited extent something of the siliceous nature of the clay. The 8.2% residue on 200-mesh screen in the Crossley clay is somewhat high for this clay and contains some impurities other than sand. The residue of the Russell and Cursey Blue clay contained black organic matter in addition to sand. The Russell clay appears to be similar to the other Maryland clays, if it were not for the large amount of sand it contains. The Enterprise clay is considered more siliceous than the Crossley and has a lower dry strength. The other Maryland clays are rather plastic and tight-burning. The Edgar clay is free from sand, is tight-burning and has a low drying shrinkage and low, dry transverse strength.

In this series, two of the three sandy clays showed a decided tendency to firecrack. In Series I, the Penna. Sandy clay body developed more cracks than any other body tested in these experiments. It is evident that the effect of sandy material in a clay tends to produce firecracking, due to the difference in the expansion and contraction behavior of the sand and clay in heating and cooling.

In this series, the four tight-burning, non-sandy clays developed considerably less cracks than the open-burning sandy ones, Crossley excepted. In Series I, the tight-burning red clay body showed less cracking tendency than the others except the Georgia kaolin body, which is so porous that cracking could hardly be expected to develop. Nothing in these experiments indicates that the tight-burning clays tend to produce firecracking. The presence of sandy material in the clay is more likely to develop firecracking than the use of tight-burning clay. These tests did not include any open-burning, non-sandy clays. Had such been included, they might have shown less tendency to crack than the tight-burning non-sandy ones.

The tendency of the clay to develop firecracking depends to a large extent on the character of the clay itself regardless of impurities, and its behavior can not be predicted in advance. While sandy material increases the tendency to firecrack, its effect may be to a large extent offset by the character of the clay, so that the amount of sandy material a clay contains can not be used as an indicator of this tendency. Thus the Crossley clay, while sandy, does not have the same tendency to crack as the two other sandy clays used.

There does not seem to be any relation between the absorption, porosity or strength of the clays in these experiments and their tendency to firecrack. From the behavior of refractories, we know that the open, porous bodies withstand temperature changes better than the tight ones, and we would expect the bodies with high porosity to have less cracking than the ones with low porosity, but the presence of sandy material and the character of the clay seem to have a much greater effect on the cracking tendency than the absorption or porosity. In Series I, the vitrified red body with only 4.79% absorption and 10.19% porosity showed much less tendency to crack than the terra cotta body with 14.90% absorption and 27.56% porosity.

Series III

These experiments were made in the same manner as Series I and II. In Series III, the same clay was used for all bodies and different kinds of grog were used as shown in the table, Series III. The different grogs were prepared in the same manner by grinding in the dry pan and passing them over the same screen. The screen analyses of the various grog are shown in the table. The trials were fired in the test kiln to Cone 6 (burn No. 5). The trials for absorption, shrinkage, etc., were fired to Cone 6 in a burn similar to burn No. 1.

The trials have been weathered six months. So far, firecracks have not developed in this series as much as in the other two series, but cracks will likely develop further after weathering.

SERIES III

Body	Grog	Dry mod. rupture lbs. per sq. in.	Per cent fire shrinkage	Per cent absorption	Per cent porosity	Modulus rupture lbs. per sq. in.
	Clay (No Grog)	262	6.85	2.79	6.05	3528
14	Saggers	185	3.56	12.13	23.37	2345
15	Kiln Slabs	158	3.34	13.05	24.76	2058
16	Fire Brick	193	3.28	12.09	23.45	2187
17	Terra Cotta	180	3.98	11.70	22.50	2278
18	Vitrified Porcelain	186	4.26	8.87	17.75	2675
20	Factory Grog thru 40-mesh	202	3.69	10.75	20.78	2554
21	Factory Grog over 40-mesh	152	3.50	13.17	25.15	1829
22	Factory Grog 33%	168	3.79	12.68	24.14	2043
23	Factory Grog 40%	173	2.66	12.65	24.76	1875

Bodies 20–23: Grog 8 Saggers, 1 Fire Brick, 1 Terra Cotta

Clay Mix { 22.5% Crossley No. 1; 22.5% Enterprise No. 30; 22.5% Cursey; 22.5% McDowell; 10.0% Edgar No. 9

GROG ANALYSES

No.	Grog	On 10	On 20	On 35	On 65	On 100	Thru 100
14	Saggers	.27	27.74	27.58	17.51	9.94	16.87
15	Kiln Slabs	.65	29.80	29.15	17.18	5.90	17.36
16	Fire Brick	.27	21.54	28.07	19.30	8.63	22.18
17	Terra Cotta	.34	19.21	23.81	18.90	11.18	26.65
18	Vitrified Porcelain	1.04	30.90	23.54	15.51	7.70	21.23
20	Factory thru 40	..	...	...	22.54	23.40	54.00
21	Factory over 40	1.04	40.40	40.32	13.65	1.04	3.56
22–23	Factory	.52	30.03	23.40	16.20	7.66	22.20

No. 19 contained grog from furnace slag, but the trials were badly overfired and swelled. This grog contained a considerable amount of iron which discolored the body. All of the bodies contained two parts clay to one of grog, except No. 23, which contained 40% grog.

No. 15, kiln slabs, and No. 23, with 40% factory grog, had two of three trials O. K.

No. 14, saggers, No. 21, factory grog over 40-mesh, and No. 22, factory grog, have two of three trials cracked. The remainder have all trials cracked. No. 16, fire brick, No. 17, terra cotta, and No. 18, vitrified porcelain, have about the same number of cracks, but No. 20, factory grog through 40-mesh, is much worse than any other of the series.

The bodies with kiln slabs and saggers have less cracking than the fire brick and terra cotta. This is due in part at least to the fact that the latter two have a higher proportion of grog finer than 100-mesh, as shown by the screen analyses. Increasing the amount of grog has reduced the cracking. The body with grog finer than 40-mesh has considerably more cracking than

the others, but the body with the grog coarser than 40-mesh does not appear to be much better than the average. Vitrified porcelain grog does not show a marked tendency to produce cracking, although the trials have a little more than the average number of cracks.

None of the grogs used can be considered as being of a highly siliceous nature. Grog containing a considerable amount of coarse quartz grains would no doubt have shown a tendency to produce cracking. Considering only the grogs used in this series, and they are representative of ordinary sources of supply in the East, the kind of grog does not seem to be nearly as important as the size and amount. It is well known that a large amount of grog finer than 40-mesh will produce cracking in the body. If the supply of any kind of grog is uniform so that in grinding it gives about the same screen analyses, the source of grog does not appear to be of great importance on the tendency of the body to firecrack. The kind of grog is of much less importance in this respect than the kind of clay.

In presenting these experiments, particularly those in Series II and III, it is recognized that they can not be considered as absolutely confirming the conclusions that were drawn from them. Had nine trials of each body instead of three been used, we might have been able to differentiate more clearly between certain mixtures. This would have made it necessary to make three burns in the test kiln on each series instead of one, which would have introduced another variable in the experiments. Further weathering of the Series III trials may show a greater difference between some of the bodies than exists at present.

While the rate of cooling has a much greater effect on the tendency of the body to firecrack than the composition, the latter is of considerable importance. There is no doubt but that a change in the composition of the body could easily produce firecracking in practice without changing the rate of cooling, particularly if the rate is somewhat rapid. The degree of sensitiveness of the bodies of various compositions to firecrack when cooled at the same rate is an indication of their ability to withstand expansion and contraction strains in service, and a number of failures of free-standing terra cotta have no doubt been due largely to expansion and contraction strains. By selecting a body that shows the least tendency towards firecracking, and cooling the kilns slowly, so that the strains set up by the contraction of the piece during cooling are reduced to a minimum, we should have a body that would have the greatest ability to withstand contraction and expansion strains when placed in exposed positions.

There have been other failures of terra cotta, when, through defective jointing or unsatisfactory construction, the pieces have become saturated with moisture and been subjected to alternate freezing and thawing over long periods of time. When such pieces are glazed or coated with an impervious slip, so that the moisture can not escape, portions of the surface

sometimes spall or break off. It has been suggested as a remedy for this condition, that a body with lower porosity and higher strength be used. This suggestion has been opposed by some, chiefly on the ground that such a body would have more tendency to firecrack and would not be so able to withstand expansion and contraction strains in service. These experiments indicate that in many cases the porosity could be lowered and the strength increased, without increasing the tendency to firecrack, by a simple substitution of clays.

These considerations seem to indicate the desirability of further and much more extensive experiments on the composition of the body and the tendency to firecrack.

CONKLING-ARMSTRONG TERRA COTTA CO.
PHILADELPHIA, PA.

NEW DEVELOPMENTS IN OXYCHLORIDE STUCCO AND FLOORING[1]

By J. B. Shaw and G. A. Bole[2]

ABSTRACT

Substitution of Calcium for Magnesium Chloride.—Calcium chloride can be substituted for magnesium chloride only under special conditions. Calcium chloride solutions must be much more dilute than magnesium chloride. Less filler can be used with magnesium chloride. Mixtures of the two chlorides do not give as good cement as either separately.

Dolomite-Calcium Chloride Cements.—Tensile strength, volume change, weathering tests, specific gravity figures are given. Some good cements are found. Some of the cements have weathered for two years.

Dolomite-Magnesium Chloride Cements.—Tensile strength, volume change, weathering tests, specific gravity figures are given. Some excellent cements are reported equal to magnesite cements with equal MgO content.

Introduction

Magnesium oxychloride cement has been used to some extent since the middle of the last century, but in view of some of its remarkable qualities it is difficult to understand why it has not found a very much more extensive use than it has. Some of the excellent qualities which have been attributed to it are as follows:

Very high tensile strength.

Low specific gravity, making a cement of great strength with little weight.

It is capable of taking a high polish.

When mixed with appropriate filler, it has a very high resilience, making it comfortable for office floors, etc.

It is not slippery.

It can be applied in a thin coat over wood or cement without cracking.

A search for the cause of the restricted use of this material revealed two serious disadvantages, namely:

(*a*) High cost.

(*b*) Frequent failure of floors laid with the cement, by cracking, buckling and expansion.

Cost

The high cost of this cement is partly due to the fact that magnesite, from which it has been made, occurs only in restricted areas far removed

[1] Received April 3, 1922.

[2] Title covering this work was given in the program of the American Ceramic Society in February 1919, much of the work having been done prior to that date, but for various reasons the material was not put into proper shape for publication until this time.

from the centers of consumption. The fact that the material has failed frequently, rendering it necessary to do the work a second time, compelled those selling it to demand a high margin of profit to ensure them against loss. These two factors have combined to keep the cost of this material so high as to restrict its use.

The prestige of this cement was greatly damaged during the latter part of the last century by certain unscrupulous manufacturers who, without making sufficient preliminary experiments to learn how properly to make it or whether it would survive under exposure to weather, used it for building blocks and built houses of them. The material crumbled away in a few years and magnesium oxychloride cement has since labored under the disadvantage of this reputation.

This paper contains some of the results of an effort to find a method of utilizing the excellent qualities of this cement by overcoming the disadvantage under which it is laboring.

Reducing Cost

Source of MgO.—As stated above, magnesites have been the only source of caustic magnesia for the cement. This is, and must of necessity remain, an expensive material.

Dolomitic limestones are very widely distributed, occurring in large quantities close to the centers of industry. The only difference, chemically, between most magnesites and dolomites is the ratio in which the constituents occur. They contain practically the same ingredients. Therefore because of its large production and easy accessibility to the centers of consumption, substitution of dolomite for magnesite would result in very material reduction of first cost of the material.

Chloride.—Calcium chloride, being a by-product from chemical processes, and not having found a very extensive use, can be obtained at very much lower cost than magnesium chloride. This substitution would result in a further reduction in cost of the finished product. Barium chloride may be used.

While it seems likely that these two substitutions would reduce the cost of the material to a point where it could be widely used, such reduction would be useless unless the quality of the material could be so controlled as to give a uniformly safe product. The results of preliminary experiments along these lines were encouraging.

The oxide of magnesia exists in two forms, the light caustic oxide (sp. gr. 3.0) and the dead burned oxide (sp. gr. 3.8). The caustic oxide is obtained by calcining compounds containing magnesium carbonate at low temperature. The dead burnt oxide is obtained by heating at high temperature, or for a long period at medium temperature. The caustic oxide will hydrate slowly with very little evolution of heat. The dead

burnt oxide will not hydrate. The caustic oxide is the form used in making oxychloride cement. The dead burnt is used for refractories.

The first question arising in considering the use of dolomite as a source of MgO is the influence of the carbonate of lime.

1. Will the presence of calcium oxide, resulting from calcining at too high a temperature, be injurious to oxychloride cement?

2. Is it possible commercially to calcine the dolomite so as to decompose the $MgCO_3$ to form caustic MgO and leave the $CaCO_3$ undecomposed?

3. Will the amount of MgO in such a limestone be sufficient to give good strong cement when diluted with the unavoidable $CaCO_3$ in the original rock?

Preliminary Experiments

The Dolomite.—In an endeavor to answer these questions a dolomitic limestone of massive form was selected having the following composition before calcining:

$CaCO_3$	55.83
$MgCO_3$	43.37
SiO_2	.14
FeO_2 and Al_2O_3	.14
H_2O organic	.52
	100.00

Magnesite.—California magnesite containing 98% $MgCO_3$ was calcined at 1000° C and tested to compare with the dolomites.

Calcining.—Fifty pounds of the rock were crushed to half-inch size and calcined in a covered sagger in a small updraft gas kiln. Thermo-couple was placed just over the surface of the dolomite.

Sample *A* was raised to 650°C in three hours and temperature held between 650°C and 700°C for three hours.

Sample *B* was raised to 770°C in three hours and temperature held between 770°C and 800°C for three hours.

Properties of Calcined Material.—Sample *A* was unchanged in appearance; color and hardness being about the same as the original rock.

Sample *B* had changed from the gray of the original rock to practically white. It was still hard but distinctly more brittle than the original rock.

Grinding.—The calcined material was ground dry in a ball mill. *A* ground slowly but left mill and pebbles clean. *B* ground somewhat more rapidly than *A* but coated the sides of the mill and pebbles. It has been noted that some magnesite calcined at 800°C to 1000° C sticks to the sides of mill and pebbles, or, in other words, balls up in the mill.

The screen analysis after grinding was as follows:

	A	*B*
On 100	1%	5%
Through 100 on 150	20	24
Through 150 on 200	15	15
Through 200	64	56

Chemical Tests.—The chemical tests for determining what carbonates and what oxides were present in the calcined material and in what proportion, were carried out by the method outlined by G. A. Bole[1] for direct determination of CO_2, also using the ammonium chloride method for active lime.

Below are given dissociation temperatures obtained on these materials.

Magnesite	470°C	Temperature at which the pressure of the CO_2 becomes atmospheric all at approximately 730° mm. Hg
Calcium carbonate	885°	
Mixture $MgCO_3$ and $CaCO_3$	470°	
†Raw dolomite	470°	

† Later investigations on many dolomites have proven this relation to hold for some dolomites only.

Determination of MgO, CaO, $MgCO_3$ and $CaCO_3$ in Calcined Material.—Total CO_2 was determined by blasting weighed sample. The CO_2 in $MgCO_3$ was determined by heating weighed sample at 700°C in an atmosphere of CO_2 until evolution of gas ceased and measuring the loss by the above-mentioned method, CO_2 and $CaCO_3$ were found by difference.

Results

		A (calcined at 650–700)	*B* (calcined at 770–800)
Total CO_2 lost by blasting		36.50%	26.50%
CO_2 lost by heating at 700°C		1.67	0.00
Calculated results	$MgCO_3$	4.5	0.0
	$CaCO_3$	70.0	60.0
	CaO	0.0	17.5
	MgO	25.5	22.5

The ammonium chloride method for free lime gave (*A*) 0.50% and (*B*) 18.2% of free lime, respectively.

The difference in CaO content indicates that a part of Sample *B* must have reached a sufficiently high temperature to decompose considerable quantity of $CaCO_3$. The effect of this free lime on the results in the physical tests is very evident.

Heat Evolved during Hydration.—This was determined by mixing 50 gr. of calcined powder with 25 cc. of water and inserting a thermometer in the mass. The method is admittedly crude and only indicates comparative values.

[1] Bole and Shaw, *Trans. Am. Ceram. Soc.*, **17**, 125 (1915).

A calcined 650°–700° } no rise in temperature.

B calcined 700°–800° } 11° rise in temperature.

Magnesite.—Calcined 1000°C } no rise in temperature.

Presence of CaO in B is clearly indicated by the rise in temperature.

Oxychloride Cements.—The calcium chloride used in making up the solutions showed the following analysis:

$CaCl_2$	95.00
$NaCl_2$	1.44
H_2O and organic matter	3.40

The solutions were made up to 20° and 25° Baumé and kept in stoppered bottles.

Standard Ottawa sand was used.

The sawdust was fine (80-mesh) and dry.

The rule adopted for making up the cements was to follow industrial practice, by adding enough solution to make all the cements up to the same consistency as far as possible. Each mix was made up to such a consistency that it would just stand without flowing. The results obtained showed this to be a mistake as the amount of solution varied greatly, making large differences in the ratio of oxide to chloride and hence detracting from the value of the data obtained because of difficulty in interpretation. Later experiments show the results obtained by varying the ratio between MgO and chloride.

Time of Setting.—Cements made with calcium chloride are slower setting than those made with magnesium chloride.

Much free calcium oxide seems fatal to the cements. Sample B showed no setting in 24 hours and even after two weeks was soft. When magnesium chloride was added to this sample, efflorescence was distinctly evident in ten hours. The white scum then started continued to collect for weeks. Qualitative tests showed these crystals deposited on the surface to be calcium chloride.

The reaction producing this result is probably as follows:

$$CaO + MgCl_2 + H_2O = Mg(OH_2) + CaCl_2$$

No efflorescence was noticed at any time on Sample A or the calcined magnesite, whether made up from magnesium chloride or calcium chloride.

Constancy in Volume.—Constancy in volume was roughly determined by laying pats of the cement on glass plates, noting cracking and measuring linear shrinkage of test bars.

A—Every cement made from this sample adheres firmly to glass plates. No cracking was noted in any trials and no measurable shrinkage.

B—Decided shrinkage. No adherence to glass plate. Not hard.

Magnesite.—All trials made up from neat magnesite show some shrinkage. An important point noted is that the neat magnesite trials made up with calcium chloride show less shrinkage than those made up with magnesium chloride.

Neat MgO with $MgCl_2$ sets very rapidly and attains great hardness but it cracks badly. Neat MgO with $CaCl_2$ gives the strongest cement made, though it sets somewhat more slowly than MgO with $MgCl_2$.

Magnesite-sand-$CaCl_2$ mixture adheres to glass plates, shows no crack and no measurable shrinkage.

Specific Gravity.—Only a few determinations have been made:

		Sp. gr.	Per cu. ft.
(C-1)	Magnesite and $MgCl_2$	2.05	128
(A-1)	Dolomite and $MgCl_2$	1.99	124
(C-5)	Magnesite and $CaCl_2$	1.87	117
(A-5)	Dolomite and $CaCl_2$	1.79	112

Sawdust is frequently used in this cement, making a very light product.

Tensile Strength.—The following tables show the results obtained on tensile strength. The briquettes were made in standard cement moulds and in making them the specifications of A. S. T. M. were followed except for the consistency of the material as above stated.

DATA SHEET

Oxychloride Cement

Using Dolomite as Source of MgO

No.	Filler	Chloride	Per cent[1]	Sp. gr. sol. deg. Baumé	C. c. sol. per 100 gr. mix	Tensile strength lbs. per sq. inch 14 days	28 days
A-1	$CaCO_3$	$MgCl_2$	54.6	25	36	540	620
A-3	$CaCO_3$	$MgCl_2$	35.9	20	32	590	720
A-5	$CaCO_3$	$CaCl_2$	48.7	25	32	80	165
A-7	$CaCO_3$	$CaCl_2$	35.9	20	32	92	125
A-9	$CaCO_3$	($MgCl_2$)	(24.4)	25	32	345	530
		($CaCl_2$)	(24.4)				
A-11	$CaCO_3$	($CaCl_2$)	(18.0)	20	32	125	295
			(18.0)				
A-2	($CaCO_3$)						
	(Sawdust)	$MgCl_2$	105.0	25	52	255	625
A-4	(Sawdust)	$MgCl_2$	44.5	20	32	475	625
A-8	(Sawdust)	$CaCl_2$	84.0	20	60	45	30
A-10	(Sawdust)	($MgCl_2$)	(48.0)	25	51	190	213
		($CaCl_2$)	(48.0)				
A-12	(Sawdust)	($CaCl_2$)	(39.0)	20	56	40	75
			(39.0)				

[1] Per cent figures on basis of 100 MgO, that is, 54.6% $MgCl_2$ equals 54.6 % of the MgO in the mix. Where sawdust is given, 20% by weight of mix was used.

DATA SHEET

Oxychloride Cement

Using Magnesite as Source of MgO

No.	Filler	Chloride	Per cent[1]	Sp. gr. sol. deg. Baumé	C. c. sol. per 100 gr. mix	Tensile strength lbs. per sq. inch 14 days	28 days
C-1	None	$MgCl_2$	18.0	25	60	105	60
C-3	None	$MgCl_2$	9.7	20	44	140	300
C-5	None	$CaCl_2$	16.6	25	52	610	1242
C-7	None	$CaCl_2$	11.0	20	50	677	556
C-9	None	($MgCl_2$)	(7.5)				
		($CaCl_2$)	(7.5)	25	50	383	902
C-11	None	($CaCl_2$)	(5.8)				
			(5.8)	20	52	540	665
C-2	Sand	$MgCl_2$	21.7	25	19	650	650
C-4	Sand	$MgCl_2$	13.4	20	16	555	610
C-8	Sand	$CaCl_2$	15.1	20	18	333	358
C-12	Sand	($MgCl_2$)	(7.5)				
		($CaCl_2$)	(7.5)	20	18	347	420

[1] Per cent figured on basis of 100 MgO, that is, 18.0% $MgCl_2$ equals 18.0% of the MgO in the mix. Where sand is given, 75% by weight of the mix is used.

No data on *B* are given in the table since no cements having any strength were obtained from it.

The high shrinkage of the neat magnesite trials is shown to have produced weak briquettes, probably due to cracks, some of which were plainly visible.

While $CaCl_2$ solution has produced the best strength with neat magnesite, the $MgCl_2$ solution gives best results when sand is added.

In the dolomite *A*, the $CaCl_2$ briquette shows tensile strength decidedly lower than the magnesite. (Later results have shown that the $CaCl_2$ solution used here was too high in sp. gr., better results being obtained with sp. gr. around 12 to 14 Bé.)

The mixtures of dolomite and $CaCl_2$ are much softer than $MgCl_2$-dolomite mixtures but the magnesite-$CaCl_2$ trials are as hard as the magnesite-$MgCl_2$ after 28 days. No explanation of this apparent inconsistency has been found.

A study of the table would seem to indicate that the following conclusions would be borne out by experience:

1. Calcined magnesite must be diluted with some coarse aggregate to give satisfactory cement with $MgCl_2$.

2. Calcium chloride can be successfully used to give strong cements with calcined magnesite.

3. Cements obtained with dolomite and $MgCl_2$ are as good as any obtained with magnesite with equal MgO content and $MgCl_2$.

4. Both dolomite and magnesite give cements of higher tensile strength than Portland cement.

The results obtained in these preliminary experiments indicated that this line of endeavor was well worth further pursuit. Three of the original questions which these experiments were designed to investigate have been answered, namely:

1. Free CaO resulting from overburning dolomite is decidedly injurious to oxychloride cement.
2. Dolomite does contain sufficient MgO to give a good cement when properly calcined.
3. Calcium chloride can be used to replace magnesium chloride only under proper conditions.

Calcining Dolomite.—One question has not been answered by these experiments, that is, as to whether dolomite can be calcined commercially so as to give a uniform product. An extensive investigation of this point was made and successful results have been obtained on commercial scale. This will be the subject of a separate paper. It may be said here that it was found impossible to burn dolomites properly under ordinary conditions of calcining these materials. A process was developed in which all conditions, especially temperature and pressure, were carefully controlled and by which successful results were obtained repeatedly on ton lots of dolomite.

Properties of Stucco and Flooring

A further study of this subject* was made by selecting different dolomites, studying their structure and properties and making tile, laying them on wood in much the same manner as floors are laid of this cement.

Tests were made to determine the effect of:

Fineness of grinding.
Temperature of cement during setting.
Humidity of the atmosphere during setting.
Strength of chloride solution.
Different kinds of coarse aggregate.
Expansion.
Weathering of finished product.

Fineness of Grinding.—In general fine ground material gives highest tensile strength. Dolomite-magnesium chloride mixtures show the following tensile strength in 7 days:

	200-mesh	100-mesh	On 100-mesh
	780	700	450
	750	680	490
	740	610	440
Average	760	660	460

*Much of this work was done in the laboratory of the Solvay Process Company in coöperation with the writers.

Our experience has been, however, that too finely ground materials are more likely to crack in setting than those not so finely ground.

Temperature during Setting.—Tile made from dolomite and $MgCl_2$ solution 18° Bé. held at 80°F set hard in two hours and developed tensile strength of 550 lbs. per sq. in. in two days. Ordinarily it requires 3 to 5 hours for final set.

Humidity during Setting.—Test pieces placed in a damp box where relative humidity was high set very slowly, developing only 50 lbs. per sq. in. in tensile strength in 7 days. Did not set after taking from the box.

Weathering.—Briquettes made from coarsely ground dolomite-calcium chloride mixtures show following tensile strength:

	7 days	14 days	2 years' exposure to weather
13° Bé.	180 lbs.	210 lbs.	390 lbs.
13° Bé.	150	200	430
14° Bé.	160	185	420

This indicates that this material does not deteriorate badly in weather.

Tile made from these same mixtures have been exposed to the weather since August 1919 and are in good state of preservation.

DATA SHEET

Oxychloride Cements
Using Dolomite as Source of MgO
Cement Tile Laid 1/2" Thick on Wood

No.		MgO Per cent fineness	Calcium chloride sol. Per cent free CaO	Sp. gr. deg. Bé.	C. c. per 100 gr. mix	Per cent	Results
10	25	7% on 100	1.0	14.3	46	30.9	Cracked but hard
14*a*	25	7% on 100	1.0	14.3	45	32	Shrinks in setting
17	27.5	100	1.0	14.3	38	19.9	Cracked, not trowelled
17*a*	27.5	7% on 100	1.0	14.3	38	19.9	Cracked, not trowelled
18	27.5	7% on 100	1.0	14.3	36	18.5	Good
19	27.5	7% on 100	1.0	14.3	31	19.9	Good
19*a*	27.5	200	1.0	14.3	31	19.9	Good
20	27.5	100	1.0	14.3	31	19.9	Good
20*a*	27.5	7% on 100	1.0	14.3	31	19.9	Good
22	27.5	7% on 100	1.0	13	31	18	Good
22*a*	27.5	7% on 100	1.0	12	31	16.6	Good
26	27.7	7% on 100	1.0	10	31	13.3	Good
26*a*	27.7	7% on 100	1.0	11	31	14.9	Good
27	27.7	7% on 100	1.0	12	31	16.4	Good
27*a*	27.7	7% on 100	1.0	13	31	18.0	Good
28	27.7	7% on 100	1.0	18	31	24.9	Sets slowly
28*a*	27.7	7% on 100	1.0	20	31	28.7	Sets very slowly, poor tile

The data in the above table indicate that calcium chloride with properly burned dolomite will give good cement.

Good results have been obtained with the tile containing from 13–25% calcium chloride (percentage based on MgO present).

When magnesium chloride is used, the percentage of chloride runs higher.

Time of Setting.—These calcium chloride cements are almost invariably slower setting than when magnesium chloride is used.

	Initial set	Final set
Dolomite-$CaCl_2$.....	40 min. to 1 hour	4 to 7 hours
Dolomite-$MgCl_2$.....	30 min. to 50 min.	3 to 5 hours

Fineness of the material and strength of chloride solution are important factors in determining time of set.

Fine material sets more rapidly.

Low sp. gr. calcium chloride solution promotes rapid setting.

Stucco.—If this material is to be used for stucco, it is essential that it withstand weathering; some of the data given above indicates that it will stand weathering if properly made. A very thorough investigation is necessary to determine many points as to how to improve its weather resistance. Other investigators, notably The Dow Chemical Company, are working on this problem and results they have obtained are worthy of note. They have investigated many brands of commercial cements as well as some which we have produced from dolomite. Incidentally it may be said that the dolomite product stands in the front rank. Their test shows the product made from dolomite compares favorably with the commercial stucco material on the market, in its ability to stand up under weathering test, which consists of making test pieces, allow them to set 14 days, spray them with water 24 hours continuously, dry 24 hours, spray 24 hours and dry, repeating for three successive days, then determine modulus of rupture (wet) and after allowing to dry 2 days.

DATA.—TESTS MADE BY THE DOW CHEMICAL CO. MATERIAL CALCINED BY SHAW AND BOLE

Analysis of Calcine Material

	Canadian magnesite	Gouvenour dolomite A-1	Gouvenour dolomite A-2
Loss on ignition.....	19.50	31.70	33.95
SiO_2.....	1.30	1.53	.37
R_2O_3.....	1.25	.97	.22
CaO.....	12.72	34.50	37.85
MgO.....	66.60	27.20	27.80

Stucco mix, using $MgCl_2$ solution 22°Bé.

Canadian Magnesite...	1	Dolomite A-1...	2.5	Dolomite A-2.....	2.5
Ground Flint.....	2	Ground Flint....	1.0	Ground Flint.....	1.0
Sand.....	5	Sand.....	4.5	Sand.....	4.5

	Tensile strength		
	1 day	3 days	7 days
Canadian Magnesite body.....	408	402	400
A-1 Dolomite body.....	..	..	467
A-2 Dolomite body.....	258	428	488

		Per cent change in length		
		1 day	3 days	7 days
Canadian Magnesite Body	(normal air).....	−.02	−.02	−.03
	(wet air).....	+.006	−.004	+.025
A-1 Dolomite Body	(normal air).....	+.18	+.28	+.31
A-2 Dolomite Body	(normal air).....	+.04	+.06	+.06
	(wet air).....	+.07	+.13	+.14

− Indicates contraction. + Indicates expansion.

		Water resistance			
		Dry	Wet	Recovered	Per cent recovered
Modulus of Rupture	Canadian Magnesite...	1614	702	1605	98.0
	A-1.....	1596	768	969	60.7
	A-2.....	1890	990	1458	77.1

Recovery of 50% or more considered good.

These tests show that high strength of dry test piece does not indicate high resistance to weather and that fine aggregate promotes weather resistance. The dolomite cement has this advantage and probably owes its high weather resistance to it. Tests which they made on Canadian magnesite shown in the table gave exceptional results.

NEW YORK STATE SCHOOL OF CLAYWORKING AND CERAMICS
ALFRED, NEW YORK

MICROSCOPIC STUDY OF GROUND COAT AND COVER COAT ENAMEL REACTIONS[1]

By E. E. Geisinger

ABSTRACT

A study of ground coat and cover coat enamel reactions showing that the degree of susceptibility of enamels to furnace gases is easily classified by cross-section examination under the microscope. The excess intermingling of the ground and cover coats and interaction between ingredients can be determined. Lack of firing range of the two coats is easily noted. The tendency of an excess gasifying of the enamel on the ware is seen. The high viscosity of enamels which do not allow the ready escape of occluded air and gases, thereby forming large bubbles and resulting weak structure, is studied. Results of overfiring and underfiring are summarized.

Introduction

We who are working with glass enamels are studying each new as well as old glass combination from every possible angle, considering such points as raw material cost, smelting properties, gravity and slip properties, and when applying to the ware, such properties as softening temperature, flowing and finishing temperature, burning range, etc. The color, gloss and general appearance are probably next registered, and finally we use innumerable schemes of comparative tests of durability to physical abuse as well as general corrosion and acid resistivity tests. It is important that we determine whether this new combination will be a constant or too frequent offender in regard to fishscaling, shivering or other poor results caused by factory conditions which are at certain periods unavoidably not ideal or even good. If the importance and help of a microscopic study of enamels are realized by our fellow workers, after hearing this paper and seeing the series of photos, the purpose will have been fulfilled.

The Microscope in the Factory

The steel is studied and controlled from a purely metallurgical standpoint, using mostly the microscope. As our work is all on heavy steel plate, not being less than $^5/_{16}''$, and our method of cleaning is the sandblast, we are not interested in the pickling properties of steel. The microscope has been found invaluable in showing extreme high or low carbon content, slag and oxide occlusions together with any other rolling defects. However, the texture of the sandblasted steel surface as it leaves the blast is examined with a low power double lens, for it has been proved to us by experience that a so-called open rough surface is best for enameling on steel. We have found that the tendency of steel working, annealing or rusting is to give an open ragged surface, which in turn helps to inhibit the fishscaling trouble. Messrs. Danielson and Souder touched very close to a key-note, we believe, when they advanced the steel surface problem relative to fishscaling.

[1] Read before the Enamels Division, St. Louis meeting, February 28, 1922.

Cross-Section Study of Enamel

Description of Method Used.—Enamel surfaces have been studied under the microscope as suggested by Mr. E. P. Poste in *Trans. Am. Ceram. Soc.*, **19,** 146 (1917) and this rather prompted us to study our enamels in cross-section. It has since been found that microscopic examination of the surface is more deceiving in many instances, for the temperature of the furnace will fine out the bubbles on the very top surface, leaving a very bad condition underneath. The cross-section views have told much more as to the true condition of the glass on the steel. If the problem is to examine the enamel from factory production, a chip is removed with the chisel, which is very easy with this thickness of steel. In the study of new enamels, however, flat rectangular test pieces are used and the enamel is applied to the very edge. A hammer blow on a small chisel, holding it close to the edge of the test piece and directing the chips out, will generally remove a few pieces of enamel quite clean to the steel or at least only leaving a little ground coat on the steel. It is found convenient and almost necessary to hold a cloth over the test piece so as to catch the small chips. Take the chips, and carefully break them between your finger tips until you get a break which presents a medium smooth surface. It is not necessary to be so careful about this break being even unless one intends to take a microphotograph, for differences in focus can be taken care of while examining. Much more can be seen by examining the real specimens, which of course is the case with anything that is not polished absolutely flat. By using a drop of sealing wax on a regular glass slide, the mount is easily made by just warming the spot of wax and imbedding your chip on edge, taking care to level the top edges in one geometric plane. An arc lamp is used with direct impinging condensed light, placing the ray so that it hits the chip's top edge surface at an oblique angle. A study at thirty-five to one hundred magnifications is generally sufficient, and will tell one very much as to what has happened to his glass while firing on the steel.

Example Series—Microphotos—Results

The following ground coat was used in the series, as the study was to be essentially one of two coat ware:

Ground Coat "A"

Silica	150
Feldspar	320
Borax	360
Soda	70
Cobalt Oxide	30
Manganese Oxide	70
	1000 Raw batch weight.

Add 10% raw silica and 5% clay at mill.

TABLE I

BLUE COVER ENAMELS—RAW BATCH WEIGHTS

Enamel	B1−	B1+	B2−	B2+	B3−	B3+	B4−	B4+	B5−	B5+
Silica	200	200	200	200	200	200	200	200	200	200
Feldspar	400	400	400	400	400	400	400	400	400	400
Soda	300	300	300	300	300	300	300	300	300	300
Borax	70	70	70	70	70	70	70	70	70	70
Cobalt Oxide	10	10	10	10	10	10	10	10	10	10
Manganese Oxide	10	100	..	..	..	..	..	..	..	..
Cryolite	..	..	10	100	..	..	..	..	..	..
Zinc Oxide	..	..	..	..	10	100	..	..	..	..
Barium Carbonate	..	..	..	..	..	..	10	100	..	..
Kalkspar	..	..	..	..	..	..	..	..	10	100
Litharge	..	..	..	..	..	..	..	..	..	..
Zirconium Oxide	..	..	..	..	..	..	..	..	..	..
Titanium Oxide	..	..	..	..	..	..	..	..	..	..
Nickel Oxide	..	..	..	..	..	..	..	..	..	..
Black Iron Oxide	..	..	..	..	..	..	..	..	..	..
(*a*) Results: Correct Fire	Good	Good	Good	Fair Porous	Good	Good	Good	Good	Good	Good
(*b*) Reducing Atmosphere	Blister Shiver	Porous	Porous	Some Fishscaled	Fishscaled	One Fishscaled	Two Fishscaled	Fair	Fishscaled	Shivered
(*c*) Overfired	Blister Shiver Porous	Blister Shiver	Porous Shiver	Fishscaled	Fishscaled	Shivered	Blistered	Shivered	Fair	Fishscaled
(*d*) Underfired	Dull O. K.	Dull O. K.	Good	Dull Good	Dull Good	Dull Good	Dull Good	Dull Good	Dull Good	Dull Good
Remarks:				"*b*" and "*c*" Reaction						

TABLE I (Continued)

BLUE COVER ENAMELS—RAW BATCH WEIGHTS

Enamel	B6−	B6+	B7−	B7+	B8−	B8+	B9−	B9+	B10−	B10+
Silica	200	200	200	110	200	110	200	200	200	200
Feldspar	400	400	400	400	400	400	400	400	400	400
Soda	300	300	300	300	300	300	300	300	300	300
Borax	70	70	70	70	70	70	70	70	70	70
Cobalt Oxide	10	10	10	10	10	10	10	10	10	10
Manganese Oxide	..	..	..	..	..	..	..	..	..	..
Cryolite	..	..	..	..	..	..	..	..	..	..
Zinc Oxide	..	..	..	..	..	..	..	..	..	..
Barium Carbonate	..	..	..	..	..	..	..	..	..	..
Kalkspar	..	..	..	..	..	..	..	..	..	..
Litharge	10	100	..	..	..	..	..	..	..	..
Zirconium Oxide	..	..	10	100	..	..	..	..	..	..
Titanium Oxide	..	..	..	..	10	100	..	..	..	..
Nickel Oxide	..	..	..	..	..	..	10	100	..	..
Black Iron Oxide	..	..	..	..	..	..	..	..	10	100
(*a*) Results: Correct Fire	Shivered	Good	Good	Good	Good	Good	Good	Good	Good	Good
(*b*) Reducing Atmosphere	Shivered	Shivered	Fish-scaled	Shivered	Fair	Porous	Shivered	Shiv-ered	Fishscaled	Good
(*c*) Overfired	Blistered Poor	Shivered	Shiv-ered	Fair	Porous	Shivered	Shivered	Fair	Shivered	Good
(*d*) Underfired	Dull Good	Good	Dull Good	Dull Good	Dull Good	Good	Dull Good	Dull Good	Dull Fair	Good
Remarks:	"*b*" and "*c*" Reaction	"*b*" and "*c*" Reaction				"*b*" and "*c*" Reaction		"*b*" Re-action		

Test pieces were used with the following dimensions: 2″ x 4″ x $^{5}/_{16}$″ thick, and all were cut from one plate of steel. A microphoto of the steel used is shown in Fig. 1.

All cover coats were milled with 3% of Johnson Porter clay. Both ground coat and cover coats were sprayed on the steel pieces. Table I gives the cover coat ingredients, and short notes as to the results of the test pieces after standing two months. The first series of twenty enamels is an attempt to compare the effect of varying one metallic oxide, which we will call the "variable," being added in a minimum quantity of 10 parts and a maximum quantity of 100 parts. In each case the cover coat is a cobalt-blue enamel, and the enamels were fired in a small gas furnace under the four conditions as tabulated, *viz.:* (*a*) Correct Fire. This meaning a temperature of 1700 degrees F and a firing period of just what my experience and judgment would tell me was correct by watching the enamel flow down and gloss over in the furnace. This firing was done by radiation, having the gas cut off entirely, and the atmosphere was oxidizing. (*b*) Reducing. This firing was done with excess gas flowing into the furnace, producing a reducing atmosphere. The piece was removed when finished. (*c*) Overfired. This firing was done at 1700 degrees F and the firing period lengthened by 100% over the time required to just correctly finish the test piece. A piece finishing correctly in four minutes was fired for eight minutes. (*d*) Underfired. This firing was done at 1700 degrees, but the pieces were removed before completely glossed out.

Two white enamels are given in Table II, as well as a brown-black enamel, this completing the series.

TABLE II

WHITE COVER COAT ENAMELS AND A BROWN-BLACK "D1"

	Raw Batch Weights		
	C1	C2	D1
Enamel	...	...	...
Silica	200	200	200
Feldspar	400	400	400
Soda	300	300	300
Borax	70	70	70
Tin Oxide	20	...	...
Cryolite	...	75	...
Black Iron Oxide	...	...	70
Manganese Oxide	...	...	20
a. Correct Fire	Good	Fishscaled	Good
b. Reducing Atmosphere	Shivered	Shivered	Fishscaled
c. Overfired	Good	Fair	Good
d. Underfired	Good Dull	Fair	Good

The most noticeable defects are noted in Tables I and II, but of most interest are the pictures of the cross-section of each enamel resulting from

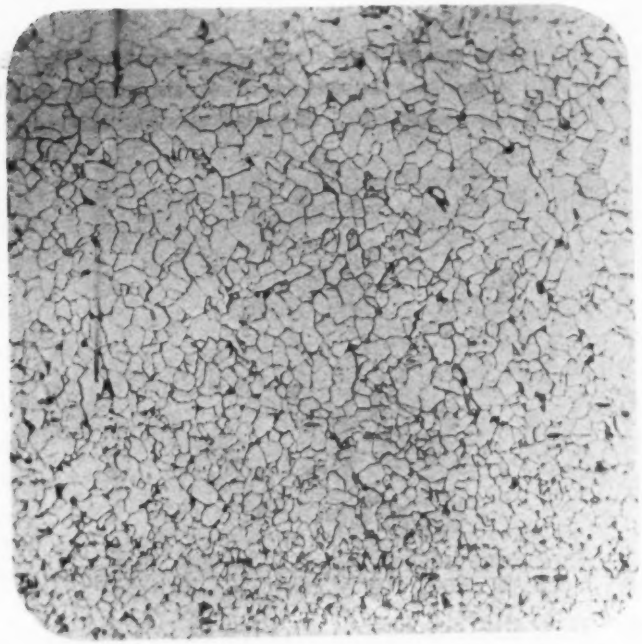


FIG. 1

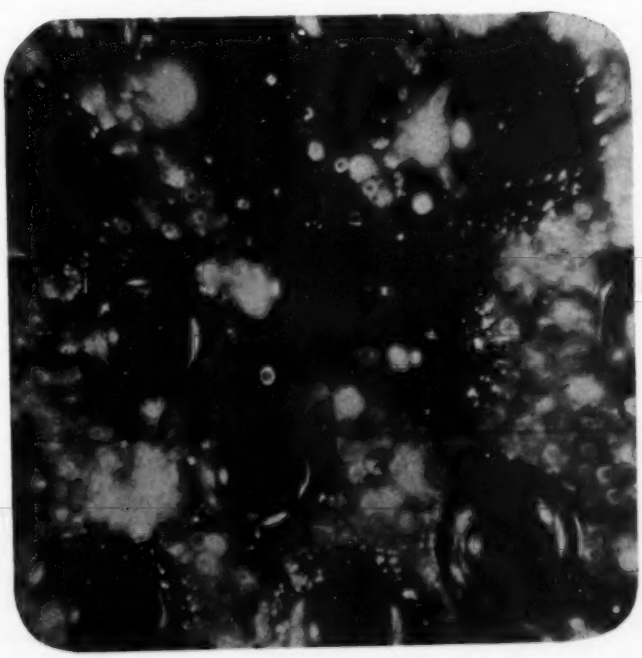


FIG. 2.

the four different types of firing. Glancing over the whole series of ninety-two microphotos, it will be noted that with very slight bubbling indications, either near the steel side or near the intersection of the first and second coat, the ground coat "A" seemed to withstand the successive firings, or in other words had a good firing range. This factor is very important in the industry of heavy plate enameling, where it is not unusual to have a tank in the furnace 40 minutes or longer, while three to four tons of steel are coming to 1700 degrees F or higher. The ground coat used in this series was one the result of which, if fired at a moderate heat beyond its range, was an enamel which would fishscale, while if fired at a higher temperature and beyond its range, it would shiver, leaving a cratered and bubbled undersurface chip as shown in Fig. 2.

In the first series of twenty enamels, the microphotographs of the correct fire all show very little heterogeneous or unmelted matrix as evident in the underfired specimens and just enough of the usual fine bubbling to make a good enamel, with the exceptions of the cryolite cover and titanium oxide cover. There is a well-defined boundary between ground coat and cover coat. An example of a correctly smelted and fired enamel is shown in Fig. 3.

If it were always possible to fire steel ware, so that no portion would receive either a too long or too short time interval, a too high or too low temperature, or a gaseous atmosphere, the need of studying enamel reactions would not attract one; but very frequently one, two or all of these conditions occur. The electric furnace has wiped out at least one of the worst enemies of glass enamels, and that is furnace gas, which may mean sulphur oxides and possibly carbon monoxide at times. The electric furnace should be appreciated in another way, and that is the capability of keeping a correct and goodly size temperature gradient near the finish of the firing.

Results of Reducing Fire.—Studying the series of enamels subjected to the reducing action of excess artificial gas, one will again see that very much as the metallic oxides are listed relative to their capability of giving up an oxygen valent, they are again listed as to the amount and size of bubbles forming in the enamels. The litharge enamels both show excessive bubbling, closely followed in this respect by titanium oxide. The titanium oxide microphotos show excessive bubbling, but very peculiarly it seemed to be located near the boundary of the cover coat and ground. The zirconium oxide enamels show a little similarity to titanium, but not as marked. Nickel oxide when added in the maximum quantity gave excessive bubbling under this treatment. The tin oxide white cover coats were not affected as severely as expected, but showed some reduction. Manganese oxide, ferro-ferric oxide, zinc oxide, calcium oxide and barium oxide withstood the test very well, and their relative position denotes the rating given them, placing manganese first.

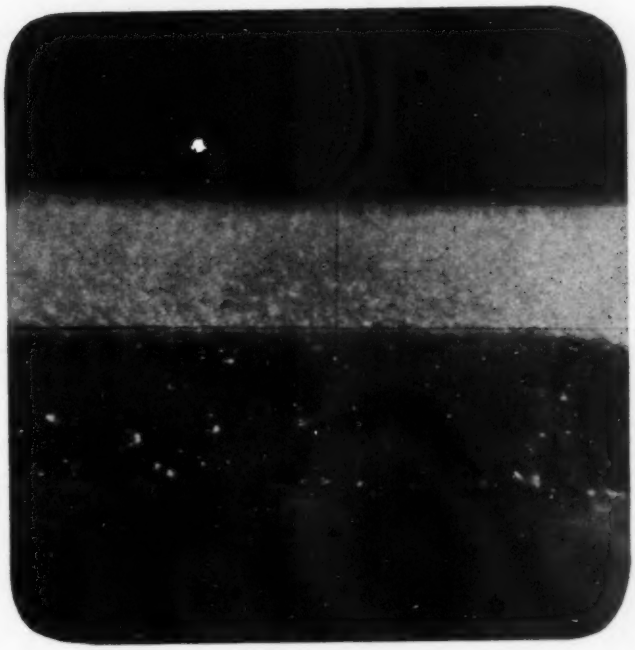


FIG. 3.

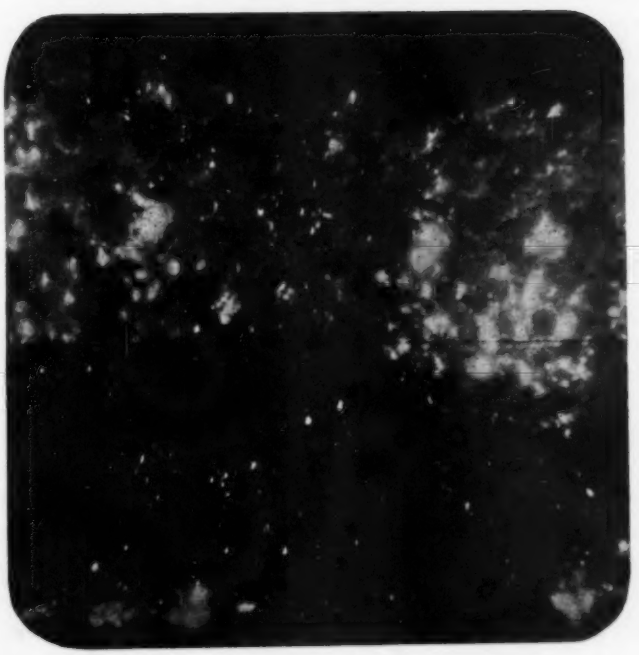


FIG 4.

Figures 4, 5 and 6 represent examples of excess bubbling under reducing atmosphere.

Figures 7 and 8 show enamels which did not easily yield to this test.

Results of Overfiring.—In the attempt to give the soft enamels a fair test the 100% extra fire system was used. The physical results of this test will be discussed later, but it is well to mention here that by referring to the tabulated chart, one will see that very few enamels survived the test. The enamel B10 plus, the maximum variable content being iron oxide, seemed to withstand the test far better than the others, the firing range being very long. The manganese oxide enamel B1 plus was very good, while enamels B4 minus, B5 minus and B6 minus, containing a minimum variable of barium, calcium and litharge, respectively, were better than the average. The enamels, however, with maximum quantities of these same oxides all shivered or fishscaled to a marked degree. The overfired sample with a minimum quantity of cryolite fishscaled and the photos in Figs. 9 and 10 are interesting in that the reasons are apparent.

Figure 11 shows a titanium enamel not listed in the series which appeared very good from the upper surface, but was likely to shiver at the least strain cause.

The cratered and bubbled condition, which did not subside to a hard glass of dense structure in the case of enamel B2 minus, made it an enamel which when expansion came to play, the edges of the craters no longer offered enough resistance and a shiver resulted. This condition or reaction, is most invariably found under a true shiver or large chip, except when caused by a very sharp convex turn in the steel piece. B2 plus or the maximum quantity cryolite enamel, on the other hand, was of such a viscosity and structure at the temperature of 1700 degrees F, lacking metallic oxides to give slight bubbling, so it densely flowed down to a solid glass enamel, melting right in with the ground coat enamel. A strain setting up in this enamel will break, not along crater or bubble boundaries of which there are none, but rather right up through the glass and a fishscale results. The condition of fishscaling and shivering has been quite generally explained by the expansion theory but it rather puzzles one to see apparently the same steel and enamel act differently. Why will the same enamel characteristically fishscale and at other times shiver, while at other times be very good? When we mention shivering, do not mistake it to include a scaling or shivering off due to dirty steel, oxide and slag occlusions or high carbon, but rather the cases which are not answered by these explanations. After examining enamels under the microscope, which included many which had fishscaled, shivered and many which were good, light on a new explanation was seen.

(*a*). An enamel which was heterogeneous in its construction, showing some unmelted matrix, did not fishscale or shiver. This enamel generally

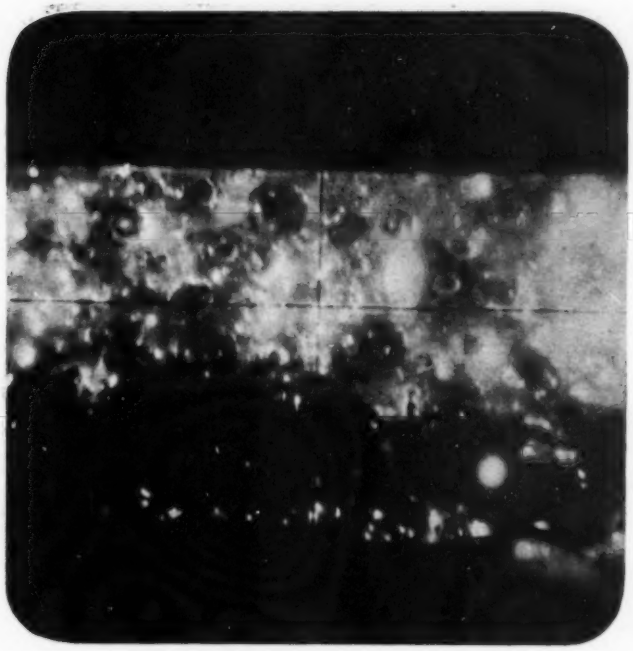


FIG. 5.

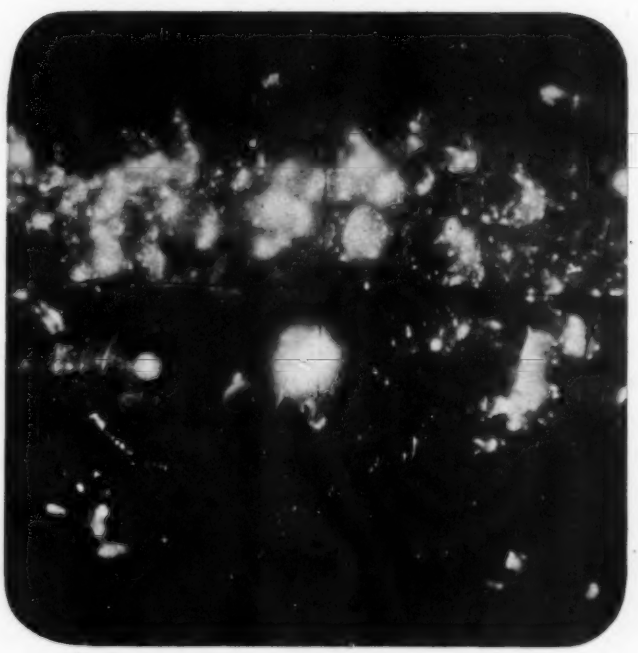


FIG. 6.

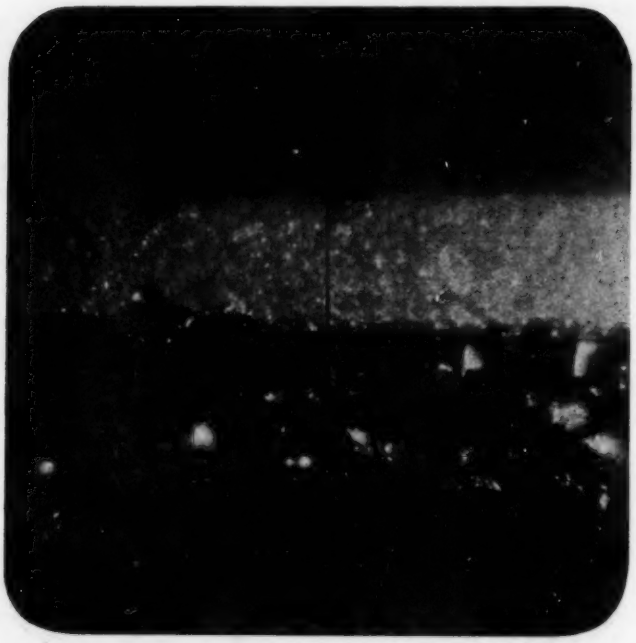


FIG. 7.

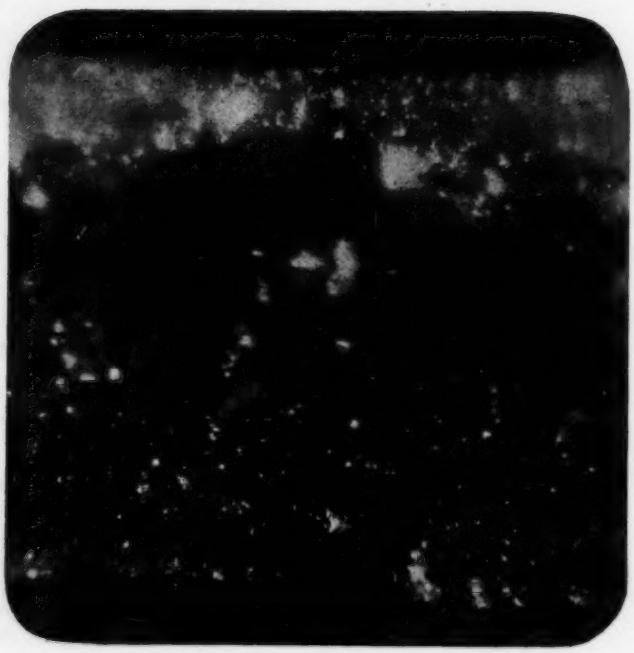


FIG. 8.

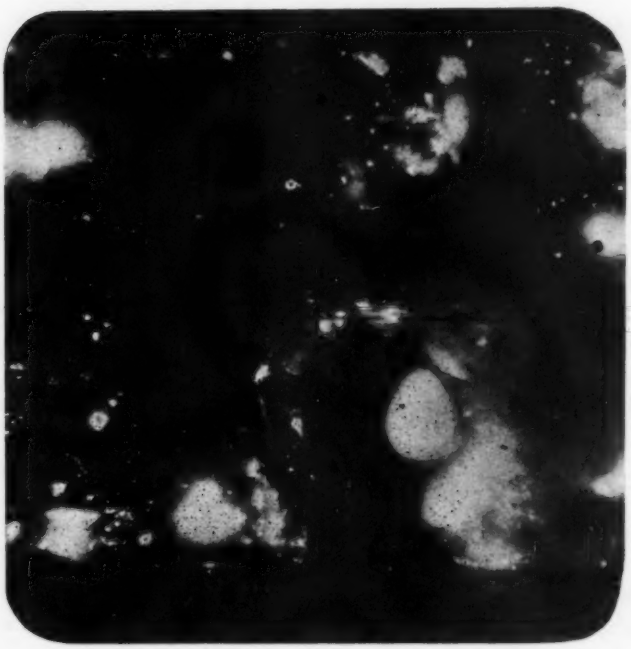


FIG. 9.

FIG. 10.

was underfired and had quite often other defects, like a dull surface, or was slightly pitted. We must conclude then that the matrix helped or eased up the expansion, even perhaps somewhat increasing the total expansion when needed to meet the steel through certain temperature changing periods, resulting in the enamel not leaving the steel.

(*b*). An enamel which showed a zone or whole cross-section of a dense, clear true glass quite generally fishscaled.

(*c*). An enamel which was excessively bubbled either in a parallel zone to the steel or in a whole cross-section would often shiver.

(*d*). An enamel which showed small uniform bubbling, not being large enough to weaken the structure, was generally free from shivering or fishscaling.

In studying Messrs. Danielson and Souder's expansion tables as well as Mayers and Hava's, it is seen that the more usable and durable enamels are a fair per cent different or rather lower in expansion than steel. Is it not reasonable to conclude that all glass enamels at best are placed under strain by change of temperature, and even at a constant temperature a strain remains?

The strength of the enamel is a main issue, as brought forward by Messrs. Danielson and Souder, and this is a logical conclusion to draw, but also let us reason and add that the resistance without fracture to this strain depends upon the physical structure and partly melted matrix. In other words, a bubbled structure is a helping hand to allow a greater give and take in the enamel until it increases to the point where the air spaces are almost, or are in excess to the true solid glass walls, and then the enamel shivers. It seems reasonable that such a structure could more easily take a lineal or cubical expansion in excess of its mean expansion, if called upon to do so. Following this thought, then, to guard against or to correct a case of fishscaling try to smelt, grind and fire to get an enamel not only of good strength and expansion, which is originally determined by the formula, but also one which has a little partly melted matrix or fine bubbles, or both, giving to the naked eye an enamel which appears glossy and dense. A guide would be to smelt so as not to get a too solid and true glass frit, regulating your batch size, time and smelting temperature preferably as low as possible. Do not mistake this to mean that the temperature of the smelter should be low before charging, for this preferably should be high thereby cutting down the time element, which is important. If possible, add a metallic oxide such as manganese, cobalt, a very little nickel or possibly iron oxide, to accelerate this bubbling when fired on the ware, which explains in part the beneficial effect found true of ground coats with a little metallic oxide addition.[1] When firing the ware, do so at as large

[1] R. D. Landrum, *Trans. Am. Ceram. Soc.*, **14,** 756 (1912); R. R. Danielson, *Ibid.*, **18,** 343 (1916).

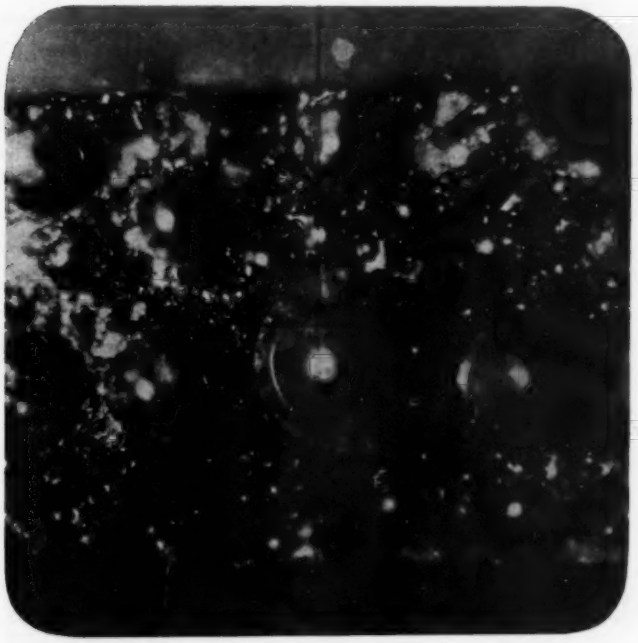


FIG. 11.

FIG. 12.

a temperature gradient as the shape and construction will allow. More skill is needed in firing this way, but the results are worth it, for the rapid fire will give the structure as mentioned above and also a good enamel in every other respect. The shorter and higher temperature firing just starts unfinished smelter bubbling or mill addition reaction, and also entraps air as very small bubbles, all of which tends to give a correct physical structure. A low heat and long firing period are conducive to fishscaling, for this is an ideal condition under which the enamel will flow down and the bubbles fine out completely or nearly so. Especially is this true if the

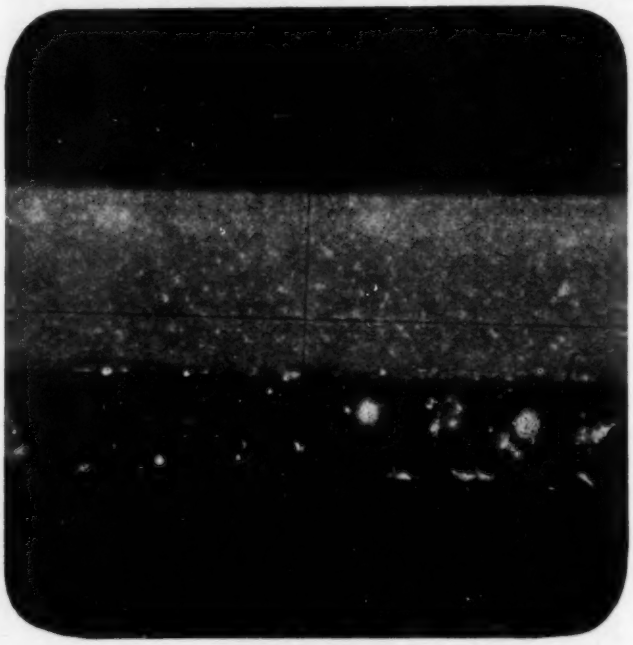


FIG. 13.

enamel is low in viscosity and low melting. Lastly a raw mill addition will tend to this structure under firing periods which are not unreasonably long or temperatures which are not too high. Most enamelers have well experienced the good effects of a raw mill addition to an enamel to remedy fishscaling, this addition generally being other than clay.

Underfiring.—The series of microphotos showing the different enamels underfired are interesting because of one fact and that is their close resemblance and structure relation to a correct fired specimen. In most instances the partly melted matrix is easily picked up under the microscope. It was rather difficult to determine the comparative period at which time the pieces were correctly termed underfired. The following are examples of underfired enamels taken from the series. See Figs. 12 and 13.

Conclusions

(*a*). The degree of susceptibility of enamels to furnace gases is easily classified by cross-section examination under the microscope.

(*b*). The excess intermingling of ground coat and cover coat, meaning that their flowing temperatures are too close to one another, as well as possible interaction between ingredients can be determined. The lack of firing range of either ground or cover coat can quickly be noted.

(*c*). The tendency of a continued excess gasifying of the enamel on the ware especially at high temperatures will be seen, as in the case of enamels containing high titanium oxide.

(*d*). The high viscosity of enamels which do not allow the ready escape of occluded air and gases, thereby forming large bubbles and a resulting weak structure, can be studied. The very opposite of this condition, causing very dense glass-like structure, can be studied.

(*e*). And, finally, the relation of all these factors in helping to explain characteristic fishscaling and shivering, which were summarized under the heading "Overfired."

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A MODIFICATION OF THE EMPIRICAL FORMULA IN GLAZE AND ENAMEL CALCULATIONS[1]

By J. E. Hansen[2]

ABSTRACT

Objections to the Usual Type of Molecular Formula.—The shortcomings, disadvantages and objections to the usual type of molecular formula are reviewed, and it is shown by calculation back to the batch mixture how the molecular formula may be misinterpreted.

New Type of Molecular Formula Proposed.—The following type of an empirical formula is proposed.

$$\left.\begin{matrix} Na_2O \ .... \\ Na_2F_2 \ .... \\ K_2O \ .... \\ CaO \ .... \\ CaF_2 \ .... \\ BaO \ .... \\ ZnO \ .... \\ PbO \ .... \end{matrix}\right\} \quad \begin{matrix} Al_2O_3 \ .... \\ Al_2F_6 \ .... \end{matrix} \quad \left\{\begin{matrix} SiO_2 \ .... \\ SiF_4 \ .... \\ B_2O_3 \ .... \\ Sb_2O_3 \ .... \end{matrix}\right.$$

Advantages of New Type.—The advantages of this new type of formula are that (1) it presents its data in the usual simple and graphic manner; (2) it indicates the mineralogical and physical condition in which most of the important constituents are introduced into the batch; (3) it admits of but little danger of obtaining the wrong batch mixture upon calculation back to the raw materials; and (4) the conclusions to be drawn from it are quite fixed and definite.

The graphic empirical formula has long been, and still continues to be, one of the methods of expressing glaze and enamel composition, as well as other ceramic mixtures. The empirical formula is an aid to the ceramist in that it is a means to the simple and graphic expression of the oxides present in a ceramic composition, but, unfortunately, there are disadvantages and objections to the use of this method.

It is not the intention of this paper to defend or advocate the use of the empirical formula as it is now considered, but again to call attention to its disadvantages and suggest a form which will relieve the situation.

Concerning the use of empirical formulas, Seger says,[3] "*the formulas merely express that the elements indicated are present in certain proportions*, and it does this in a simple and graphic manner, from facts which can only be deduced from an analysis of the material."

Edward Orton, Jr.,[4] referring to empirical formulas, states that "these methods are merely mechanical aids to expression, and are not in themselves a correct statement of chemical fact."

[1] Read before Enamels Division, St. Louis Meeting, Feb. 28, 1922.

[2] Industrial Fellow, Mellon Institute of Industrial Research of the University of Pittsburgh, Pittsburgh, Pa.

[3] "Collected Writings of Seger," **2,** 562 (1902).

[4] *Trans. Am. Ceram. Soc.*, **3,** 80 (1901).

Homer F. Staley[1] says, "it is a decided disadvantage that the formulae are based on a recalculation of the gross analysis of the material, *thus neglecting the mineralogical and physical condition in which the various elements are introduced.* These neglected factors may be vastly more important when comparing two mixes than the formal similarity of ultimate analysis. If, to obviate this limitation, we try to work with empirical formulae, and at the same time keep in mind our batch, our problem becomes as complex as working with batch weights, thus annulling its one great advantage, *i. e.*, its graphic character."

Ross C. Purdy[2] says, "The alkalies introduced into glazes as a constituent part of a frit have very different influence according to the difference in their source."

Another objection lies in the placing of fluorine as F_2 in the acid group, for the fluorine is not introduced, present, or liberated as free F_2. Hence, calling it F_2 leads to a misconception of chemical fact. Further, it is the usual custom, in comparing two mixes, to consider the fluorides as minerals and not as mixtures of the oxides,[3] to which we arbitrarily calculate them in the usual molecular formula.

Therefore, it is proposed that, instead of using the regular form of empirical formula, a modified or enlarged form be used, in which, for the main part, instead of calculating the various fluorides over to the corresponding oxides (as is done in the regular molecular formula), they be incorporated into the formula as the fluoride and placed in their regular place in the formula, according to whether their oxide is basic, amphoteric, or acidic in character.

For example, take an enamel, which, according to the usual method of expressing the molecular formula, has the following composition:

$$\left.\begin{array}{l} 0.357\ Na_2O \\ .083\ K_2O \\ .172\ CaO \\ .080\ BaO \\ .242\ ZnO \\ .066\ PbO \\ \hline 1.000 \end{array}\right\} \quad 0.120\ Al_2O_3 \quad \left\{\begin{array}{l} 1.016\ SiO_2 \\ .244\ B_2O_3 \\ .044\ Sb_2O_3 \\ .323\ F_2 \end{array}\right.$$

In calculating the above empirical formula back to the batch formula, it would be usual to make the assumption that all B_2O_3 is to be derived from borax if it is possible to do so without adding too much Na_2O, that as much K_2O shall be derived from feldspar as is possible without introducing too much Al_2O_3, that all F_2 comes from fluorspar and cryolite, all CaO from fluorspar, all BaO from $BaCO_3$, ZnO from zinc oxide, PbO from litharge,

[1] *Trans. Am. Ceram. Soc.*, **13,** 123 (1911).
[2] *Ibid.*, **13,** 195 (1911).
[3] *Ibid.*, **13,** 502 (1911).

TABLE I

CALCULATION OF MOLECULAR FORMULA TO BATCH FORMULA

Formula											Material used	Molecular parts	Formula weight	Batch weight	Batch for 1000 melted
Na_2O	K_2O	CaO	BaO	ZnO	PbO	Al_2O_3	SiO_2	B_2O_3	Sb_2O_3	F_2					
.357	.083	.172	.080	.242	.066	.120	1.016	.244	.044	.323					
..	..	.172	..	..	..	..	...	..	..	.172	Fluorspar CaF_2	.172	× 78	13.42	68.5
										.151					
.075	..	..	..	..	..	.025	...	..	..	.151	Cryolite $6NaF.Al_2F_6$	$\frac{.151}{6}$	× 420	10.58	54.0
.282						.095									
.055	.032	..	..	..	..	.095	.732	..	..	..	Feldspar $.367\ K_2O \{1.1\ Al_2O_3 \{8.45\ SiO_2$ $633\ Na_2O \}$	$\frac{.095}{1.1}$	× 695	60.10	307.0
.227	.051						.284								
..	..	..	..	..	..	..	.284	..	..	..	Quartz SiO_2	.284	× 60	17.04	87.0
.122	..	..	..	..	..	..	...	.244	..	..	Borax $Na_2O.2B_2O_3.10H_2O$	$\frac{.244}{2}$	× 382	46.60	238.0
.105															
..	.051	..	..	..	..	..	...	..	..	..	Potassium Nitrate KNO_3	.051	× 202	10.30	52.5
.105															
..	..	..	..	..	..	..	...	..	..	..	Soda Ash Na_2CO_3	.105	× 106	11.13	56.8
..	..	..	.080	..	..	..	...	..	..	..	Barium Carbonate $BaCO_3$	.080	× 197	15.75	80.2
..	..	..	..	.242	..	..	...	..	..	..	Zinc Oxide ZnO	.242	× 81	19.60	100.0
..	..	..	..	..	.066	..	...	..	..	..	Litharge PbO	.066	× 223	14.72	75.0
..	..	..	..	..	..	..	...	..	.044	..	Antimony Oxide Sb_2O_3	.044	× 288	12.66	64.5
														232.50 equals 196.0 melted	1183.5 equals 1000 melted

and Sb_2O_3 from antimony oxide, using flint and clay, if necessary, to fulfill the requirements for Al_2O_3 and SiO_2. However, in studying this formula, it is found that all the K_2O could not come from feldspar because there is not enough Al_2O_3; neither can it be assumed that all the Al_2O_3 comes from feldspar and the balance of the K_2O from pearl ash or saltpetre, because then the F_2 can not be balanced up by the usual assumption that it comes from fluorspar and cryolite.

Hence, it is necessary to start our calculations with fluorspar, supply the remaining F_2 from cryolite, and take the balance of the Al_2O_3 as the index of the feldspar used.

The calculations of this empirical formula back to the batch mixture, using a feldspar of the composition

$0.367\ K_2O$	$1.100\ Al_2O_3$	$(8.47\ SiO_2)$
$.633\ Na_2O$		
1.000		

with a molecular weight of 695, are shown in Table I.

However, upon comparing this batch formula with the *original* batch formula from which this empirical formula was derived, it is found that the fluorspar, cryolite, quartz and soda ash are materially higher than they should be, that feldspar is lower, and that two constituents, namely, sodium silicofluoride and whiting, are missing entirely.

TABLE II

	Original batch# formula for 1000# melted	Batch formula for 1000# melted as calculated from empirical formula
Feldspar	342	307.0
Quartz	50	87.0
Borax	238	238.0
Soda Ash	50	56.8
Potassium Nitrate	50	52.5
Barium Carbonate	80	80.2
Zinc Oxide	100	100.0
Litharge	75	75.0
Whiting	30	...
Fluorspar	45	68.5
Cryolite	30	54.0
Sodium Silicofluoride	40	...
Antimony Oxide	64	64.5

The theoretical melted percentage composition, as shown on the following page, also differs from the composition of the original batch.

This variation in the batch formula is due to the fact that the empirical formula neglects the mineralogical and physical condition in which the various elements are introduced, and, hence, can not be correctly inter-

TABLE III

THEORETICAL MELTED PERCENTAGE COMPOSITION

	Original batch	As calculated from empirical formula
Silica	29.80	31.03
Silicon Fluoride	2.22	...
Alumina	5.51	4.95
Aluminum Fluoride	1.20	2.16
Boric Oxide	8.71	8.71
Sodium Oxide	8.66	8.87
Sodium Fluoride	3.58	3.24
Potassium Oxide	4.02	3.97
Calcium Oxide	1.68	...
Calcium Fluoride	4.50	6.85
Barium Oxide	6.22	6.23
Zinc Oxide	10.00	10.00
Lead Oxide	7.50	7.50
Antimony Oxide	6.40	6.45
	100.00	99.96

preted. That this variation would lead to an enamel of vastly different physical properties than the original enamel is, no doubt, undisputed.

However, if the empirical formula is expressed as below

$$\left.\begin{array}{l} 0.274\ Na_2O \\ .083\ Na_2F_2 \\ .083\ K_2O \\ .059\ CaO \\ .113\ CaF_2 \\ .080\ BaO \\ .242\ ZnO \\ .066\ PbO \\ \hline 1.000 \end{array}\right\} \quad \begin{array}{l} 0.106\ Al_2O_3 \\ .014\ Al_2F_6 \end{array} \quad \left\{\begin{array}{l} 0.974\ SiO_2 \\ .042\ SiF_4 \\ .244\ B_2O_3 \\ .044\ Sb_2O_3 \end{array}\right.$$

it will be seen at a glance in exactly what mineralogical and physical condition most of the constituents are introduced. The simple graphic form of the expression is still retained, and it is no longer necessary to keep in mind the batch formula when comparing two mixes as to their physical properties.

An examination of this modified form of expression shows the ingredients of the enamel, as evidenced by the following "mental analysis:"

1. Since this is evidently a cover enamel and the use of clay or aluminum oxide unlikely, the amount of soda-potash feldspar in the enamel is indicated by the content of Al_2O_3. In cases where it is evident that K_2O was not introduced in any other form, it could also be taken as an index of the amount of feldspar.

2. The K_2O in the feldspar used is approximately one-third that of

TABLE IV

CALCULATION OF MOLECULAR FORMULA TO BATCH FORMULA

Formula														Material used	Molecular Parts	Formula weight	Batch weight	Batch for 1000 melted
Na_2O	Na_2F_2	K_2O	CaO	CaF_2	BaO	ZnO	PbO	Al_2O_3	Al_2F_6	SiO_2	SiF_4	B_2O_3	Sb_2O_3					
.274	.083	.083	.059	.113	.080	.242	.066	.106	.014	.974	.042	.244	.044					
..	..	..	..	.113	..	..	..	..	..	..	..	..	..	Fluorspar CaF_2	.113	× 78	8.81	45.0
..	.042 .041	..	..	..	..	..	..	..	.014	..	..	..	..	Cryolite $6NaF.Al_2F_6$	.019	× 420	5.88	30.0
.061 .213	..	.035 .048	..	..	..	..	..	.106	..	.813 .161	..	..	..	Feldspar $.367K_2O \mid 1.1Al_2O_3 \mid 8.45$ SiO_2 $.633Na_2O \mid$	.106 1.1	× 695	67.00	342.0
..	..	..	..	..	..	..	..	..	..	.161	..	..	..	Quartz SiO_2	.161	× 60	9.66	49.3
.122 .091	..	..	..	..	..	..	..	..	..	..	..	.244	..	Borax $Na_2O.2B_2O_3.10H_2O$	.244 2	× 382	46.60	238.0
..	..	.048	..	..	..	..	..	..	..	..	..	..	..	Potassium Nitrate KNO_3	.048	× 202	9.70	49.5
.091	..	..	..	..	..	..	..	..	..	..	..	..	..	Soda Ash Na_2CO_3	.091	× 106	9.65	49.3
..	..	..	..	..	.080	..	..	..	..	..	..	..	..	Barium Carbonate $BaCO_3$	.080	× 197	15.75	80.2
..	..	..	..	..	..	.242	..	..	..	..	..	..	..	Zinc Oxide ZnO	.292	× 81	19.60	100.0
..	..	..	..	..	..	..	.066	..	..	..	..	..	..	Litharge PbO	.066	× 223	14.72	75.0
..	..	..	..	..	..	..	..	..	..	..	..	..	.044	Antimony Oxide Sb_2O_3	.044	× 288	12.67	64.5
..	..	..	.059	..	..	..	..	..	..	..	..	..	..	Whiting $CaCO_3$	.059	× 100	5.90	30.0
..	.041	..	..	..	..	..	..	..	..	..	.042	..	..	Sodium Silicofluoride Na_2SiF_6	.0415	× 189	7.84	40.0

Al_2O_3. Hence, that K_2O was introduced into this enamel, no doubt as either the carbonate or the nitrate, is evidenced by the fact that K_2O in the empirical formula is greater than one-third the value for Al_2O_3.

3. That flint or quartz also was used is evidenced by the fact that the SiO_2 in the empirical formula is greater than $.106 \times 7.7$, which is the amount of silica in the feldspar.

4. That cryolite was used is evidenced by the fact that .014 equivalents of Al_2F_6 are included in the formula. This also accounts for .042 equivalents of Na_2F_2.

5. That sodium silicofluoride was used is shown by the corresponding equivalents of unaccounted for Na_2F_2 and of SiF_4.

6. Borax, antimony oxide, calcium carbonate, fluorspar, barium carbonate, zinc oxide and litharge are used, as is evidenced by the B_2O_3, Sb_2O_3, CaO, CaF_2, BaO, ZnO and PbO in the expression.

7. Soda ash or sodium nitrate must be used to supply the remaining Na_2O needed.

That this modification of the empirical formula can be calculated back to the batch formula without so much danger of obtaining the wrong batch mixture can be seen by comparing the batch mixture as calculated below with the original batch mixture.

This scheme of arrangement violates no stoichiometrical relations and is in no way contradictory of the old type of empirical formula, but merely enlarges upon it. Further enlargement can be made if desired, such as separating the alkalies introduced with the feldspar from those introduced as soluble salts. Barium fluoride would be treated like fluorspar and entered as BaF_2. If B_2O_3 be introduced as boric acid, this would no doubt be evident from the intermolecular relationship of B_2O_3 and Na_2O in the empirical formula, but if desired B_2O_3 as introduced from boric acid could be designated as $B_2O_3.3H_2O$, as in the glaze formula below:

$$\left.\begin{matrix} .10\ K_2O \\ .20\ Na_2O \\ .40\ CaO \\ .30\ PbO \end{matrix}\right\} \quad .40\ Al_2O_3 \quad \left\{\begin{matrix} 3.15\ SiO_2 \\ .40\ B_2O_3 \\ .10\ B_2O_3(3H_2O) \end{matrix}\right.$$

Hydrated oxide of aluminum could also be treated in a similar manner as $Al_2O_3.3H_2O$.

The presence of lepidolite, which is gaining favor as an enamel material, would probably be indicated by the presence of Li_2O in the empirical formula, for it is unlikely in the ordinary enamel that Li_2O would be introduced as the more expensive carbonate. In calculating an enamel containing lepidolite back to the batch formula it would be necessary to figure the lepidolite before attacking the feldspar and alkalies.

If ZrO_2 appears in the empirical formula, the intermolecular proportions of ZrO_2 and SiO_2 (considered with the feldspar) may indicate whether the

ZrO_2 was introduced as the oxide or silicate. In case there is no such easily apparent relationship, one might have to make an arbitrary choice.

This modification does not clearly establish the source of Na_2O as to whether it is introduced as the nitrate or carbonate, and it is not within the scope of this paper to discuss what difference their interchange would make in the physical properties of an enamel, but it is believed that this form of expression possesses sufficient other redeeming qualities to warrant its use. Neither is it claimed that this modification of the empirical formula is a correct statement of chemical fact as regards the state of combination of the various constituents of the fritted mass, for the equilibrium relations attained will depend on the temperature and length of time of smelting, but the author knows of no expression which can state this relation.

The advantages of this modification of the empirical formula are as follows:

1. It presents its data in the usual simple and graphic manner;
2. It indicates the mineralogical and physical conditions in which most of the important constituents are introduced into the batch;
3. It admits of but little danger of obtaining the wrong batch mixture upon calculation back to the raw material; and
4. The conclusions to be drawn from it are quite fixed and definite.

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THE PLASTICITY OF CLAYS[1]

By F. P. Hall[2]

ABSTRACT

Discussion of the term "plasticity" and the methods brought forward for the measurement of plasticity; the factors which each measures; the use of the Bingham plastometer as an instrument for determining relative plasticity of clays; the need for more efficient methods of measuring plasticity.

Introduction

The idea of plasticity as held by ceramists may be defined as the property which enables a body, soft enough to be moulded without cracking, to retain its shape permanently after it has been subjected to a deforming pressure. The bonding power of the dried clay is another distinct property and should not be implied when speaking of plasticity. The plasticity of clays has been attributed to the presence of matter in a colloidal state. It is known that the size of the grains of a substance markedly affects the plasticity of the substance. It has been shown that extremely fine-grained clays and extremely coarse-grained clays are less plastic than clays composed of both fine and coarse grains mixed. It is highly probable that the distribution of grain-sizes which permits the closest packing of particles will be most favorable to high plasticity. The compact mass resulting from the close packing of particles will evidently offer the greatest resistance to being deformed. Clays exhibit many properties common to substances in the colloidal state such as: hydrolysis, absorption, shrinkage, ability to change from gel to sol form and *vice versa*. This analogy between clays and substances in the colloidal state has led investigators to look to the field of colloidal chemistry for a possible solution of the problem of plasticity.

From the above discussion of plasticity we see that there are two factors to be considered in measuring this property, namely: (1) resistance which a clay offers to changing its shape; (2) the amount of deformation which a clay can suffer without cracking. Mellor[3] suggests that the following formula is the mathematical definition of the term plasticity:

$$\text{Plasticity} = \frac{\text{Cohesion}}{\text{Internal friction}}$$

Cohesion can be represented as the amount of deformation that a clay can suffer without cracking and internal friction as the resistance that a clay offers to changing its form.

[1] Published by permission of the Director, U. S. Bureau of Standards.

[2] Received April 10, 1922.

[3] "On the Plasticity of Clays," by J. W. Mellor, Communication from the Clay and Pottery Laboratory, Stoke-on-Trent No. 53.

Methods of Measuring Plasticity

Numerous methods have been brought forward for measuring this important property of clays but few can be recommended due to the fact that the methods are empirical and do not measure plasticity but some property closely allied to it. Many methods proposed for measuring plasticity are based on the bonding power of the dried clay. This bonding power of the dried clay is a distinct property of the clay and should not be confused with the plasticity. We will not consider these methods in this article.

On account of the heterogeneity of the system clay–water it is very difficult to formulate mathematical equations that will satisfy the observations. With most of the methods it is very difficult to obtain concordant results. The apparent wetness or consistency of a clay-water mixture is influenced by several factors, namely, (1) past history of clay, (2) type of clay, (3) amount of working the mixture has received, (4) time of contact of clay and water, (5) temperature of mixture, (6) amount of water. Some of these factors are not easily controlled and hence it is difficult to obtain results that are satisfactory.

The first method to be considered is the dye-absorption test. Ashley assumed that the plasticity of a clay was inversely proportional to the grain size, and hence the clay that had the highest colloidal content was the most plastic. Plasticity is not, however, entirely due to the presence of colloidal matter in clays, though the effects of colloids in increasing plasticity can not be denied. In determining the colloid content Ashley used the dye-absorption test. The absorption of a clay is usually determined by noting the loss of color of a dye solution, such as malachite green, and comparing it with another similar solution to which a standard clay has been added. It is known that different colloids have different absorptive powers towards a single dye and it is not reasonable to assume that the colloidal matter in all clays is the same, hence this method of determining the colloid content is open to a serious objection. In other words, in order for this method to be correct the colloidal matter in different clays would have to have the same absorptive power and this is not the case.

Method of G. E. Stringer and W. Emery

It is known that plasticity varies with the proportion of water mixed with the clay. The possible plasticity is that which can be developed under the best known conditions. The possible plasticity of a clay can not be developed by commercial methods unless the material is in a state which may be regarded as dormant plasticity. Messrs. Stringer and Emery have measured the relations between the proportion of water in the clay and the resistance the clay offers to changing its shape, and the deformation

the clay can suffer without cracking. Their method is briefly: A sphere of clay mixture is made 2 cm. in diameter. This sphere is placed upon a glass slab and this placed under a vertical piston. Weights are added to the piston to cause it to descend upon the clay sphere. The descent of the piston is stopped when vertical cracks appear on the edge of the disc. The distance moved by the descending piston is taken to represent the amount of deformation the clay could suffer without cracking; and the weight required to compress the clay sphere a definite distance is taken to represent the resistance the clay offered to changing its shape. They found by this method that as water is progressively added to a clay, the plasticity increases to a maximum and then as more water is added the plasticity gradually decreases. The chief difficulty with this method seems to be in making the clay sphere. Cylindrical test pieces are not as satisfactory as spherical ones. The results are expressed in plasticity units which are empirical. It is difficult to obtain concordant results and the method will have to be modified before it will be satisfactory. It was found that the greater the plasticity of the clay, the greater the proportion of water required to develop the maximum plasticity. A ball clay required 30 per cent of water before becoming sticky, a kaolin required 20 per cent, while a very short clay required only 10 per cent of water to make it sticky.

The MacMichael Torsional Viscosimeter

This instrument was first brought forward to determine the so-called "viscosity" of clay slips. It is at present used to determine the viscosity of liquids. It will be shown later that clay slips are not liquids but plastic substances. The torsional viscosimeter is an instrument for determining the viscosity of a liquid by a torsional balance, usually consisting of two concentric cylinders, one of which has an angular motion about their common axes. One of the cylinders is suspended by a fine wire, thus forming a torsional pendulum. In the MacMichael instrument the outer cylinder rotates at constant speed. The inner cylinder rotates until the torsional force in the suspending wire balances the viscous resistance, and then remains in a fixed position so that a reading may be taken. In the case of viscous liquids if the speed of rotation of the outer cylinder is plotted against the angular deflection of the inner cylinder, the result will be linear and pass through the origin. If a plastic substance is tested the result will be linear at high speeds but the linear portion of the curve extended will not pass through the origin but will intersect the deflection axis at a definite point above the origin. Clay slips behave like plastic substances in this instrument. This instrument has been tested out at the Bureau of Standards with different clay slips. The results are not reproducible, due to what may be called a "puddling effect." Thus as the outer cylinder rotates, that part of the slip immediately surrounding

the inner cylinder changes in consistency as the stirring continues. Another difficulty in testing clay slips in this type of instrument is that of filling the outer cup to the proper height. In dealing with a substance that does not flow freely under its own weight it is very difficult to pour the substances into a container so that the entire surface will be at the same level.

This "puddling effect" observed in this type of instrument is likely to be present in any instrument designed for this type of substance as long as the agitation is local and does not extend to the entire mass. In a clay slip the particles are not free to move about, hence we have local agitation within the outer cup immediately surrounding the inner cylinder and this agitation changes the apparent wetness of this part of the slip. This instrument in its present form can not be recommended for the testing of clay slips. The curves obtained by testing clay slips with this instrument are very similar to those obtained with the Bingham instrument which will be described in another portion of the article.

The Emley Plasticimeter

This instrument is described in Bureau of Standards Technologic Paper No. 169 by Mr. Warren E. Emley. Mr. F. A. Kirkpatrick and Mr. W. B. Orange used this instrument for testing clays and limes and made a report of the results in an article in *Journal of the American Ceramic Society*.[1] The results are expressed in a term called the "plasticity figure" which is empirical depending upon the dimensions of the instrument. Mr. Emley states that the consistency has little influence upon the plasticity. This is not consistent with the definition of plasticity as commonly given by the ceramist. The ceramist recognizes the fact that the plasticity is greatly affected by the water content of the clay mixture. There seems to be a difference in the definition of plasticity as given by the ceramist and that given by the plasterer. Hence the plasticimeter is not measuring the same property that is designated as plasticity by the ceramist. The plasticimeter measures the property of retaining water and the resistance to deformation under pressure that a substance possesses. This instrument gives a measure of only one of the two factors of plasticity and an additional factor, namely, the property of retaining water. This instrument seems to have given good results for the use of plasterers and investigators of lime and plaster because in this field the term plasticity does not have the same meaning as in the field of the clay worker. This instrument in its present form can not be recommended to the clay worker as an instrument for determining the property which he calls plasticity.

[1] *Jour. Am. Ceram. Soc.*, **2**, 44 (1919).

Atterberg Plasticity Method[1]

This method is based upon the varying physical behavior of clays with different water contents. The range of water content over the workable stage is determined. The workable stage is bounded by two points which are arbitrarily fixed, one point being that at which the clay mass will barely flow and the other the point at which the clay mass can no longer be rolled into threads. It is Atterberg's contention that the wider this range the more plastic is the clay. The results are expressed in a unit designated as the "plasticity number," which is empirical. This "plasticity number," along with the per cent water of plasticity, is supposed to determine the plasticity of the clay.

It is evident that in a method of this type too much is left to the judgment of the person conducting the tests. For comparative tests this method seems to have met with a fair degree of success.

The Bingham Plastometer[2]

If clay be suspended in water the fluidity is lowered rapidly and in a perfectly linear manner. As the proportion of clay increases a concentration is reached where the fluidity is zero as measured in an ordinary viscosimeter. Thus these instruments are not available for measuring the viscosity of suspensions above that critical concentration where the substance ceases to act as a viscous liquid. Prof. E. C. Bingham has developed an instrument for the investigation of substances of plastic nature. In using this instrument the rate of flow through a capillary tube under a definite constant pressure head is determined. The flow at several pressures having been determined, the volume discharged per second is plotted against the pressure producing the flow. For true viscous liquids the relation is linear and passes through the origin; for plastic substances the relation is linear at high pressures but if this linear portion of the curve is extended to the pressure axis it will not intersect the axis at zero but at a finite point on the pressure axis. Fig. 1 illustrates this difference between the two states of substances. The fact that with plastic substances the linear portion of the curve does not pass through the origin shows that with substances in this state a certain defi-

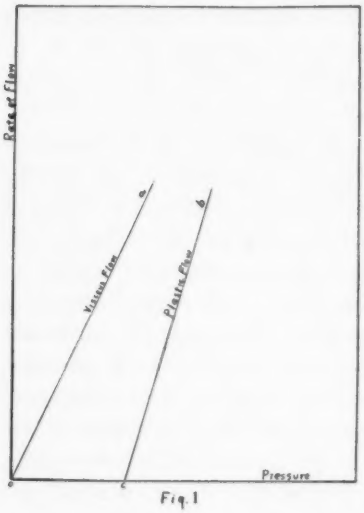

Fig. 1

[1] Technologic Paper of the Bureau of Standards, No. 46.

[2] Proceedings, *Am. Soc. Test. Mats.*, **19,** II (1919), **20,** II (1920).

nite pressure must be exceeded before the substance will flow. This definite initial friction value that has to be exceeded distinguishes the plastic state from the viscous state. The experiments by Bingham support the definition by Maxwell (Theory of Heat) that a plastic body is one in which the body is found to be permanently altered when the stress exceeds a certain value. The following relation between certain terms is given by Bingham and Green:

Solids (including plastic materials)		Liquids
Rigidity (R)	comparable with	viscosity (η)
Mobility (μ)	comparable with	fluidity (θ)
$\mu = \frac{1}{R}$		$\theta = \frac{1}{\eta}$

By reference to Fig. 1 the terms will be explained. The slope of the line a is determined by the fluidity of the liquid, while the slope of line b is determined by the mobility of plastic material, and the intercept of the line b upon the pressure axis is determined by the initial friction value of the plastic material. This initial friction value is also designated as yield value. Of two clay slips of equal mobility, the one having the higher yield value is the more plastic, while of two clay slips of equal yield value, the one having the higher mobility is the more plastic.

Plastic clay in the form of a cylinder or cube, for example, will maintain its form provided pressure due to weight does not exceed the yield value. Once the yield value is exceeded the material will flow. If the material is very mobile it will flow with ease; if not, a greater pressure will be required to keep the material in motion. These two factors, mobility and yield value, may be said to define roughly the plasticity of a substance. This conception of plasticity seems to be a more rational definition than that commonly given by ceramists.

The action of different clay-water mixtures is shown in Fig. 2. The mobility of clay-water mixtures can be varied by changing the water content. The practice followed in determining relative plasticity by this method is to make up a clay slip of one of the clays and determine the mobility and yield value of this slip, then take a second clay and vary the water content of the second slip until the mobility is the same as the first, using the same capillary as before. The mobility being constant, the plasticity will vary directly as the yield value.

Fig. 2 shows a comparison between an English ball clay and an English china clay. The ratio $\frac{W}{C}$ is the ratio of water to clay in the slip. Both determinations were made using the same capillary and the results are comparable. The slopes of the lines are the same. The English ball clay has a yield value of 395, while the English china clay has a yield value of 50.

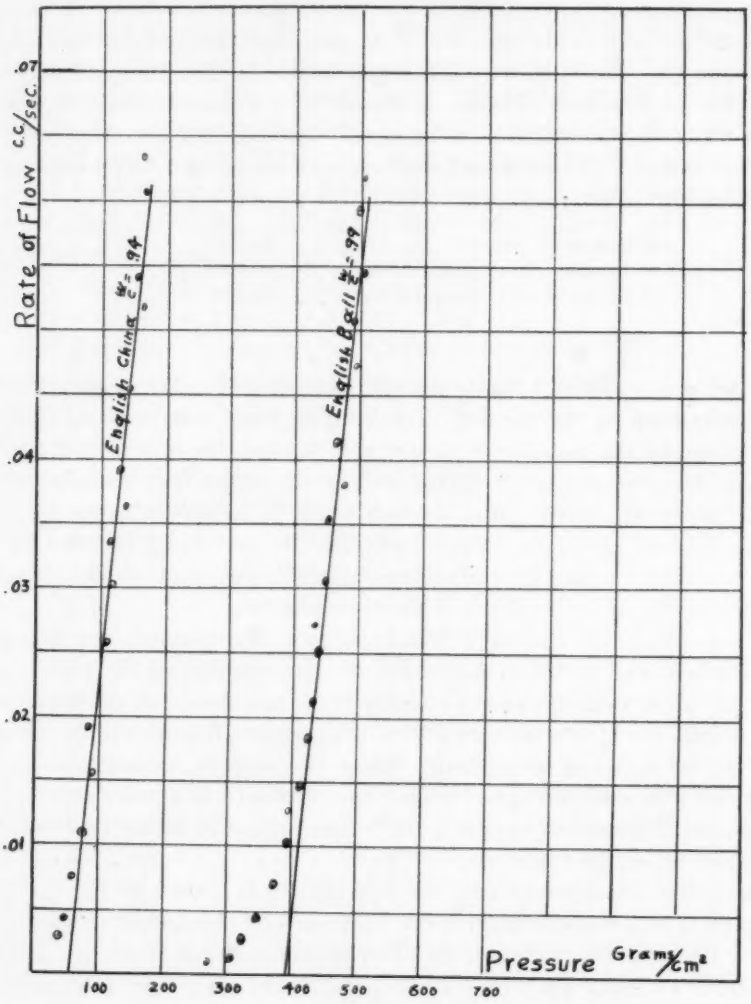

FIG. 2.

No attempt will be made to reduce these results to C. G. S. units. Bingham and Green applied their plastometer method to the investigation of the plasticity of paints and correct mathematical equations for the plastic flow of paints through capillary tubes have been worked out by Dr. E. Buckingham,[1] of the Bureau of Standards. A great deal of work has been done, at the Bureau, on the study of the plastic flow of clays through capillary tubes, and it has been found that the equations for plastic flow of paints do not hold true for clay slips. Hence the results will remain empirical until equations are derived that will satisfy the observations.

[1] Proceedings, *Am. Soc. Test. Mats.*, **21**, 1154–56 (1921).

It is possible, by the use of larger capillaries and higher pressures, to examine mixtures of clay and water, in which the proportion of water is a great deal less than that shown in Fig. 2. This method measures the resistance to plastic flow through capillary tubes. The Bureau of Standards is now investigating the theory of plastic flow of clays through capillary tubes and hopes to publish something additional in the near future.

Conclusions

It is evident in surveying the methods brought forward for measuring this fundamental property—plasticity, that none of the methods are perfectly satisfactory. It seems that it is a resultant of two factors or perhaps more. If it be true that there are two or more essential factors which determine the plasticity of a substance, then there can be no true unit of plasticity. In most of the methods brought forward the authors have attempted to express their results in some unit or number which is supposed to define the condition of the material. Bingham's conception of plasticity seems to be the most rational one of all. The greatest difficulty seems to be in defining the term "plasticity" and then sticking to that definition when attempting to measure that property. There is great need for more efficient methods of measuring "plasticity" and a clearer understanding of the factors which influence it. Plasticity, to the technologist, is in about the same category as the term "colloid," to the chemist.

TABLE I

Plasticity, as defined by Mellor, resolves itself into two factors, *viz.*, (1) the resistance that a clay offers to changing its shape, and (2) the amount of deformation a clay can suffer without cracking.

Method of measuring plasticity	Property actually measured, units	Remarks
1. Ashley dye-absorption method	Absorptive power of clays for dyes Unit-grams dye absorbed from standard dye solution	This is an attempt to measure the colloidal content of clays, but as all colloids do not have the same absorptive power for the same dye, it measures the absorptive power of colloids present and not the colloidal content. It is yet to be proven whether or not the colloidal content is an index of plasticity.
2. Stringer and Emery method	Measures two factors of plasticity as defined by Mellor "Plasticity units" (empirical)	It is difficult to obtain concordant results and method is unsatisfactory.
3. MacMichael torsional viscosimeter	Viscosity of liquids by a torsional balance Unit — the MacMichael degree	The method is not applicable to testing of clay slips as they behave as plastic solids and not as viscous liquids.

TABLE I (*Continued*)

Method of measuring plasticity	Property actually measured, units	Remarks
4. Emley plasticimeter	Property of retaining water and deformation under pressure Unit—"Plasticity figure" (empirical)	This instrument measures only one of the factors of plasticity.
5. Bingham plastometer	Resistance to plastic flow through capillary tubes	Method based on the definition of a plastic substance as given by Maxwell. This theory of plasticity seems more rational and has a wider application than that usually given by ceramists.
6. Bleininger efflux viscosimeter	Resistance to flow through an orifice under a single uniform pressure	This instrument measures the flowability of a slip, and is not applicable to slips of low water content.
7. Atterberg method	Range of water content over the workable stage Unit — "Plasticity number"	It is Atterberg's contention that the wider this range the more plastic is the clay.
8. Various other methods such as Vicat needle test, A. Brongmat's wad-box, P. Jachum's bending test, and K. Dummel's spiral test	Measure deformation	These instruments measure only one of the two components of plasticity.

LAMINATION, DISCUSSION OF CAUSE AND CURE

By J. J. Fred Brand

ABSTRACT

Discusses types of laminations, *differential* and *interfacial;* the volume relations of clay and water in pugged clay; laminations produced in auger machines; effect of die on lamination; effect of pugging; effect of working upon the character of clays; conclusions.

Lamination and dryer difficulties are the most serious and baffling problems of the clay worker. Losses due to lamination and in drying are great, not only in terms of ware totally destroyed, but also in decreased quality; thus, if not rendering otherwise satisfactory clays entirely unavailable, restricting their use to the lower grades of ware.

Two Types of Lamination.—Lamination refers to the faulty structure in which one or more planes of cleavage occur between layers of formed clay. It may conveniently divide into two forms; first, that which arises from the differential flow of the clay through the machines and which may be properly referred to as *differential lamination;* and second, that which results from an imperfect union of formed masses of clay, *interfacial lamination*. The former embraces the so-called die and perhaps the repress lamination and the latter, auger and core-bridge lamination.

Differential Lamination.—In all processes where pugged clay is made to flow under pressure, the differential type will be produced to a greater or less degree, die lamination in the molding machine, and repress lamination in the repress. While it may not always be apparent in the product, yet it can usually be seen at some stage of the molding process, varying largely with the character of the clay, the pressure applied and the resistance offered to the flow of the clay. This type, when well developed, presents a scaly or lamellar structure, the planes of cleavage separating thin strata or layers of clay.

Interfacial Lamination.—Interfacial lamination is peculiar to wares made by stiff-mud machines which are equipped with either, or both, augers and core-bridges. In this the planes of cleavage are few compared to those of the differential type and occur at less frequent intervals separating thick sections rather than thin layers.

When both the differential and interfacial types are present in the same piece (as in ware from an auger machine) it is not at all times easy to distinguish between the two. Usually, however, there is less bond between the sections of the interfacial type than between the scales of the other, and under severe drying conditions the piece is apt to fail first along the lines of interfacial lamination.

Core-bridge lamination results from the inability of the clay to properly unite after having been separated by the yoke which sustains a core. Thus this type is peculiar to hollow-ware.

Repress lamination may be attributed to a differential flow of clay in the mold along planes other than those produced by the primary machine. Ordinarily this form does not present the scaly structure of that produced by the differential flow in the molding machine.

Volume Relations of Clay and Water in Pugged Clay.—Clays are made up of varying percentages of a variety of mineral particles and aggregates, ranging in size from those which require a further reduction to those that are sub-microscopic. When water is added to such a mass, a portion is adsorbed by the grains, another portion occupies the voids between the grains, thus in effect serving as a filler. This is generally known as pore water.

Another portion occupies the minute spaces between the clay grains and pools of filler water and forms the medium through which the attractive forces act to bring the mass together. Proceeding on this assumption, there is now formed between the grains and pools of filler water, a system of capillary channels of equal area throughout the mass. This portion may be referred to as capillary water. The ability of the moist mass to retain its shape after molding is largely if not altogether due to the attractive forces acting through this portion of the water. The mass is now at its maximum density, any addition or removal of water causing an expansion. At this stage the mass is incapable of taking up additional water without the aid of an outside agency.

To give the mass flowing qualities such as are demanded by stiff-mud machines, a final addition of water is necessary. Its introduction causes a distension of the capillary channels and, with them, the mass. It decreases rigidity by its action as a lubricant. This portion may be referred to as water of moldability or water of distention, or in the drying as shrinkage water.

Granular clays which contain considerable quantities of filler water naturally permit the use of less water of moldability than those clays which, because of a lower content, possess greater initial rigidity. Thus it is impossible to obtain as good flowing qualities in the former as in the latter without encroaching upon the standing qualities of the mass.

In a properly pugged clay, the layer-like water distended channels, which criss-cross in every direction, would be of uniform thickness; each layer or channel presenting its edges to the surface of the mass in ridgelike protuberances so that in the bringing together of two masses of wetted clay, the conditions should be ideal for their perfect union as nothing is involved except the sticking together of what to all practical purposes are two wetted surfaces. It would seem that the advantage would lie with the plastic clays, since in these the channels are more numerous and consequently least tolerant to lines of cleavage, yet both the molding and drying difficulties have multiplied very rapidly with plasticity. In fact the

more plastic clays have been wholly unadapted to the manufacture of those wares in which the structural qualities are vital.

Laminations Produced in Auger Machines.—To form a clear conception of the effects produced, let us assume a machine having a perfectly fitting auger, being full of clay and in motion with the die closed. As there is no possibility for the escape of any clay from the machine, there can be no forward movement, consequently that portion of the clay within the influence of the auger must rotate with it. If now an opening be made in the die, allowing the escape of only a portion of what the auger could deliver (the condition under which auger machines operate), then one of two other things must occur: (1) either a part of the mass will stop rotating and move toward the opening, while the balance continues its rotation, or, as is more likely, (2) the whole of the mass rotates while moving forward. The rotation is greatest near the auger surfaces, while the forward movement is greatest in the portions farthest away. This results in a differential flow of the clay and in the formation of differential laminations in the threads of clay within the auger. (Fig. 1*a*.)

Obviously this differential twisting continues after leaving the auger, gradually abating, however, as the mass recedes from the auger. Between the auger and die we have a zone in which the clay is rotated at many different speeds. This results in the breaking up of the laminated structure previously formed in the threads, and in the formation of a new structure (Fig. 1) the cleavage planes of which stand in a position paralleling the face of the auger and arranged helically around its axis. Among the lines so formed there may be found at intervals those which mark the surfaces of the clay streams which were produced within the auger.

The polishing effect of the auger upon the clay has often been given as a cause for auger lamination. It is obvious, however, that these polished surfaces cannot withstand the differential rotation which obtains between the auger and die. Close inspection reveals that they are roughened just as they leave the auger and come into contact with the preceding coil which is rotating at a slightly slower speed.

As the clay mass moves through the die, the shape of the laminated sections becomes modified, the extent of which is governed by numerous factors, among them: (1) the capacity at which the machine is being operated, (2) the relative capacity of the auger and die, (3) the design of the forming members, (4) the character of clay, (5) the state of its temper, (6) the flowing qualities, (7) the resistance offered to the movement of the column by the cutting mechanism, etc.

Ordinarily, however, there is a forging ahead of the center portions of the column, which is more pronounced, other factors remaining the same, when the supply of clay is ample than when low, forming the laminae which are of a saucer shape near the auger, into a series of

FIG. 1*a*.—Group showing Figs. 1, 2 and 3.

FIG. 1.—Section taken in front of an auger showing an auger lamination plane to good advantage. Cleavage planes near the edges result from differential flow.

telescopic sleeves or cones. The resulting formation perhaps never extends to the center of the clay column on account of the flow of clay which fills the void left by the auger shaft.

Effect of Die on Lamination.—Except for the abrupt change from the larger circular throat to the smaller most generally rectangular-shaped die, it is not probable that the walls of the forming members exert the influence that has been generally presumed. It has been said that the clay flows with greater ease upon itself than upon the metal parts of the die, and that this gave rise to differential flow causing the so-called die lamination. That clay does not flow upon itself with greater ease, especially in the case of a well-lubricated die, is shown by the fact that while a smoothly worn auger barrel lining is worthless to keep the clay from floating with the auger, a corrugated lining which immediately becomes clay-plastered, has a high degree of efficiency.

Fig. 3 shows a piece made while the supply of clay to the auger was low. It will be noted that except as the laminae have been crimped into a zig-zag or herringbone effect, they stand as originally formed. That even the outer surfaces were not affected by reason of having been in contact with the metal parts of the die or forming members is shown by the fact that the lay of the laminae is against the flow.

Since differential flow results from the resistance encountered in the molding, the unitiated might conclude that the proper course would be to select a plastic free flowing clay, or develop that quality to the utmost in the clay at hand and reduce as much as possible the frictional surface of the forming members by shortening the distance between the delivery end of the auger and the point where the clay leaves the machine and to introduce lubrication at a point as near the auger as possible. The most that would have been accomplished by such measures would be reduction of pressure and differential flow.

Machines designed on these theories have been successful only with the most easily flowing clays while those designed on quite opposite theories have been more generally successful. This is especially true in the working of the more gritty shales and clays, which offer greater resistance to passage through the machine.[1] In the working of these, instead of doing the most to promote their easy flow, just the opposite has been done. Not only is there ordinarily a greater difference between the capacity of the auger and die than in machine operating in plastic clays, but we often find extra long dies and throats in use which cannot but increase pressure and resistance and with them, differential flow. If we compare the products of these machines such as paving brick with that of the sewer-pipe press in which there is no twisting, we will find in most cases that the former has much the better structure, regardless of the fact that ordinarily clays of the same

[1] Bleininger and Ross, *Trans. Am. Ceram. Soc.*, **16**, 392 (1914).

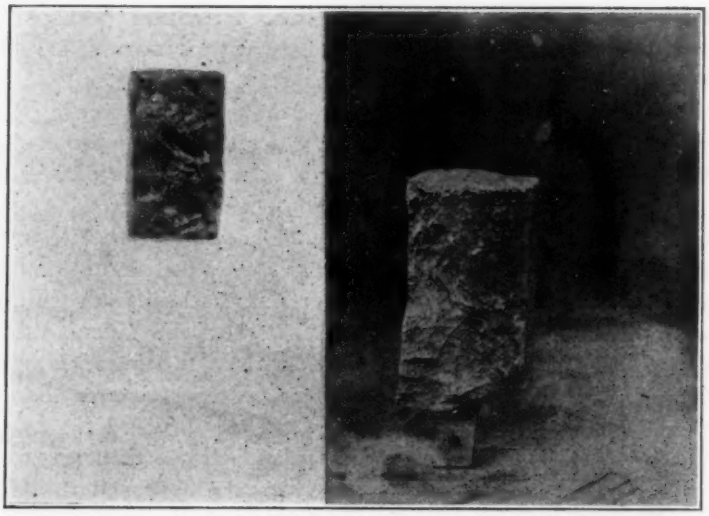

FIG. 2.

FIG. 3.

general character are used in each, and that the latter usually possesses any advantage which the wet-pan confers.

Add to the above the uncertain effects of various degrees and methods of pugging, one becomes engulfed in a series of complications. In the one we do the logical thing by increasing the capacity of the forming members and secure results in the direction of those anticipated, while in another situation we apply the same reasoning and the same methods that are positively disastrous. But by doing the seemingly illogical thing at a most illogical time we may succeed in not only practically removing the ill effects due to differential lamination, but also many of those arising from auger lamination.

Effect of Pugging.—The generally acknowledged superiority of the wet-pan as a pugging device over the common pugmill, because of the better results obtained, has led many to believe that the elimination of lamination was only a question of sufficient preparation, yet one can not but be impressed by the structural qualities of the older stiff-mud products, commonly made through an unlubricated die, of clays which are now considered the most troublesome and which received their preparation in no better device than the soak-pit. A method of tempering, which if more excellent than modern devices, does not derive its qualities because of any ability to produce a more intimate mixture of the various minerals present with water.

The writer is familiar with a plant which grew from a very crude one to a modern institution. The method of manufacture in its early days consisted of spading the clay from the field into carts and, after the addition of one or two buckets of water, it was taken to the plant and fed directly into an auger machine. Ancient methods perhaps, but there was no lamination, a fact attested to by the bricks in the old walls. Later after the plant had become modernized, lamination became a very serious problem. The older heads always insisted that the troubles came with the pugmill.

Figure 5 shows several pieces made of clay which passed through a disintegrator and smooth rolls and then pugged to soft-mud temper in a soft-mud machine in which it laid for seven months afterwards. When taken out it was of a temper which permitted its molding in an auger machine through which it was run. Comment is quite unnecessary.

On the other hand, witness the value of that action obtained between the auger and die, as has been noted elsewhere in the working of the gritty clays. That the value of this pugging action is not confined to any particular type may be shown by the fact that if we return any clay to the machine often enough, differential lamination will largely if not altogether disappear, depending upon conditions which will be touched upon later. But because of the fact that the clay comes into contact with the auger each time, auger lamination is not effected to a marked degree. The same results,

except that auger lamination would also be effected, could be procured by sufficiently lengthening the distance between the auger and die. While the number of returns to the machine or distance between the auger and die to obtain a given result will vary widely with clays of varying characteristics, yet the difference in the character of the clays is not fairly represented by this variation. The flowing qualities of the clays necessarily enter as a factor. Obviously, an easy flowing clay does not receive the same treatment in a machine of a given design as a clay which offers greater resistance. Power expenditure would perhaps serve as a better standard by which to measure these characteristics. It may be added in passing that this treatment, that is, returning the clay to the machine several times in succession, causes clay to become short, instead of developing plasticity.

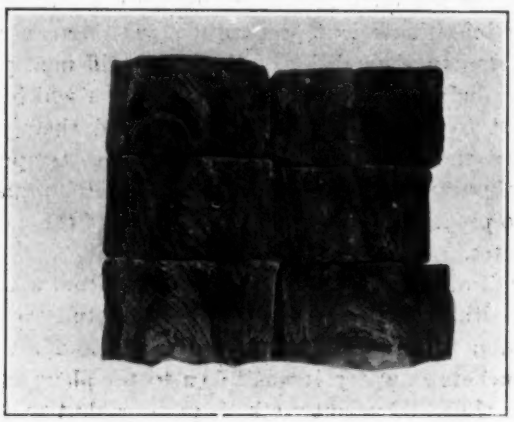

FIG. 4.

The remedial influence of differential flow is further shown by the fact that either or both differential and auger lamination are often more pronounced in the earlier stages in the machine or molding than in the product of the die.

If differential flow is a large factor in the cause of differential lamination, how may this fact be reconciled with the fact that it also acts as a remedy?

Take a given clay and run it through a given machine. We will assume that a mass of relative thick layers or scales of clay separated by comparatively few lines of cleavage are produced. We return this mass to the machine and run it through again, giving us more lines of cleavage with a corresponding thinning of the clay layers; we repeat the operation causing more lines of cleavage and thinner plates of clay and so continue until it is no longer possible to subdivide the clay layers. We no longer have alternate lines of inordinate strength and weakness and the resulting

effect is about as would be obtained by the use of a clay of lower plasticity under other conditions. In other words, the mass would be so thoroughly laminated as to be harmless in effect.

Such success as has been obtained in the elimination of the difficulties incident to lamination has resulted from measures which either increased or decreased the resistance to the flow of the clay through the machine. The most far-reaching results have been attained by the first, as the method is particularly adapted to the more granular clays. The same holds true in situations where it is possible to add granular material to the more plastic varieties. The method, however, requires that everything possible must be done to bring about a maximum resistance; otherwise only an intermediate structure is possible.

In the working of the easy-flowing clays in which the structure develops slowly, the procuring of a satisfactory state of homogeneity is ordinarily impossible because of the limitations of the machines. In these clays we would restrain as much as possible the formation of cleavage lines. To this end we would use a machine which offered the least possible resistance to the flow of the clay.

FIG. 5

But why can not a machine whose power is measured by tons do what can be done between the thumb and fingers? Why should the mere assembling of clay granules around a center point or in any other imaginable position cause lines of cleavage separating layers of clay thicker than the granules? Certainly none of them have any choice as to which other granule it will or will not unite. That the fault is not fundamentally in the nature of the machine is shown by the operation of an auger machine which was fitted with a hollow-ware die. In this the die was placed about twenty inches from the face of the auger and produced ware of a very poor structure as shown in Fig. 5, lamination being produced in the long extension as outlined elsewhere. Due to the method used in the preparation of the clay, it often became necessary to remove and clean the die. It was always found that that portion of the laminated clay which had been left in the extension near the auger would come through the die without lamination.

It has been advanced that the glutinous or colloidal character of clays promotes the formation of slippery surfaces, first by the effect of the auger, and again by the flow of the clay upon itself. As to the first, it has already

been noted how the smooth surfaces of the clay streams are destroyed by the differential twisting as they leave the auger and, if differential flow destroys such a surface, it cannot produce one. In the finished ware, the surfaces of the laminations never present any but a decided roughness, at least as rough as the granular character of the clays permit, never a slipperiness. On the other hand if these surfaces were smooth and slippery we would have all the more reason for expecting them to unite; for if we take two sections of the polished clay streams from the auger or two pieces of ware from a dry die even, and bring them together with a slap they will unite perfectly. But if these surfaces are only slightly marred, they will not unite.

The addition of grog or other granular material to plastic clays has been used with some success as a palliative, but certainly not because its granular character served to prevent the clay from slipping upon itself, for the clay no matter what its physical character may be, must twist or pass through the forming members without friction.

But whether or not the twisting or differential flow causes slippery surfaces, and whether or not the clay streams from the auger escape into the column with their smooth surfaces, in either or both cases the surfaces should be either smooth or rough. Why, then, does auger lamination so persistently remain under conditions which mitigate or perhaps entirely eliminate the effects of differential lamination?

Slow drying has a wholesome effect—and this when the conditions would seem the least favorable; for the union of the laminations can not be completed until maximum shrinkage has been reached and the clay to all purposes has become dry. It would seem that the most favorable moment for their union passes after the clay has passed the machine and begins to dry.

Effect of Working upon the Character of Clays.—That the ordinary methods of working have a marked influence upon clay is shown by the following:

Plastic clays direct from the fields, when in a condition approximating a stiff-mud temper, slake very slowly in water. The same clay after not too thorough pugging disintegrates rapidly into larger units, which in turn slake slowly.

After passing through the auger machine, disintegration, while no more rapid than before, breaks up into smaller units, which also slake slowly. After several times through the machine, disintegration approaching slaking is rapid and thorough, the mass immediately breaking up into very small units.

A significant circumstance touched upon above is the fact that the clay after several times through the auger machine becomes short, the cause of which can not be attributed to any physical change in the clay itself.

If anything, such intensive working should tend to develop plasticity. The swelling of the clay-bar as it leaves the die does not represent a relief from true compression.

The foregoing, brought out in numerous experiments and observations, convinced the writer that neither the character of the clays nor the kind of machines used formed a satisfactory basis for explaining the difficulties attending the molding and drying of clay wares.

Effect of Air.—After eliminating these as probable causes, search was continued in other directions. Air as a possible cause was suggested by the fact that the ware blistered badly as a column left the die. An examination showed that the blisters were formed by the outer layers of clay which left the mass at cleavage lines. Immersion of a brick in water showed measurable quantities of air coming from the piece as it disintegrated.

Desiring to ascertain the approximate quantity contained in a newly made brick measuring 9″ x 4″ x 2½″ an apparatus was arranged which would permit the dissolving of the piece in water and the measuring of the air thus set free. To this end, a pot-shaped shell of a steam trap with a removable cover was connected to the burette of an Orsat apparatus. A gage glass open at its upper end was fitted to the side of the shell; this for the purpose of keeping the water in it at a constant level throughout the experiment.

The method of operation consisted of filling the burette with water in the usual manner. The shell was filled to such a height so that when the brick was introduced, the water would overflow through the gage glass. After the piece had been immersed, the cover was quickly put on and the stopcocks to the burette opened. By this method, which seemed of sufficient accuracy, for our purpose, we found as much as 30 cc. of free air in several samples.

Lacking, at the time, the means to put the theory to test under conditions which would approximate actual practice, a quantity of laminated ware from the off-bearing belt was made into a slip and boiled by steam to remove the air. This was then cast into molds and allowed to dry to a stiff-mud temper, after which it was run through the auger machine.

The column came through without the slightest traces of lamination, as the sample showed. The clay was then returned to the machine several times, until it began showing a few lines of lamination due to a re-incorporation of air. But it was not until the clay had been grated through a screen and then wadded into balls, in order to more thoroughly inclose air, that lamination reappeared to a degree approximating its regular form.

The drying qualities of the airless unlaminated pieces were all that could be desired, as neither that which was run through the dryer with other ware

nor that which was placed upon the bare coils of a steam rack dryer suffered the slightest deterioration in structural qualities.

These results led to the construction of a small machine which would permit the use of a vacuum pump, thus approximating commercial conditions. Our first attempt in which we tried to remove air from a tempered mass resulted in failure, so far as commercial practicability was concerned. The difficulty did not reside so much in the obtaining of high vacuum conditions in the presence of moisture, as in the fact that as soon as vacuum conditions were obtained, the outer portions of the clay pieces became very dense and tough, thus preventing the removal of the air from the interiors. Somewhat better results were obtained by finely disintegrating the clay through a screen, but even by this method from twenty to thirty minutes were required before any marked effect was registered.

FIG. 6.

Further experiments developed the fact that commercially practical speed and results were procurable by removing the air from the clay previous to and during the tempering process.

Clays so treated become very tough and dense and practically, if not altogether, immune to the slaking action of water. This is true not only of the naturally sticky clays, but in a large measure also of the leaner varieties. This indicated to the writer that the absence of air in the interior of the clay mass and the pressure of the atmosphere play an important part in the phenomena of plasticity.

The clay used in these experiments was one of those limey varieties of glacial origin found near the shores of the lower lakes, used extensively in the manufacture of soft-mud brick. The more plastic portion of it was only fairly well adapted to the stiff-mud process in the manufacture of brick

and hollow-ware whose cross-sectional areas did not exceed 5″ x 8″. Larger pieces would collapse before reaching the cutter. Its tendency to laminate and crack in drying was frightful. The ware was very difficult to handle from the off-bearing belt on account of the shortness of the clay, though it exhibited a fair degree of plasticity before pugging. However, when tempered and pugged under vacuum conditions, it showed a surprising degree of tenacity and ductility. Instead of the characteristic rottenness as under the ordinary methods of working, it required some strength to pull apart a bar measuring $1^1/_2$ x $1^1/_2$″, the clay drawing down to a very small area before separation.

"Joint" clays treated by the vacuum process survived the most severe drying conditions. Pieces as large as walnuts stood, without cracking, a temperature which was sufficiently high to also expel the chemical water. A piece about the size of a half brick was dried without cracking in a bake oven which was previously heated to a temperature above 200° C, though the same clay, after a few moments' working by the hand, would shatter under much less severe conditions.

Conclusions

Clays which have been tempered and pugged in air contain varying quantities of occluded air, some of which become divided into blebs small enough to be contained in the water-filled channels without causing their distension or a separation except in local areas. The remaining portion, however, occurs in pockets of a larger volume than can be contained in local areas at low pressure. When such a mass is brought under pressure as in the auger machine, these larger pockets, together with the clay inclosing them, become flattened into alternate layers of clay and air.

If the clay be of the smooth, plastic, free-flowing type, offering a minimum resistance to its passage through the machine, the laminated mass escapes into the column with no substantial change in structure, except as modified in its passage through the die. If, however, it is returned to the machine several times in succession, it will result in the gradual breaking up of the heavier air layers into thinner and more numerous layers and finally into blebs which can be contained in the pores without causing their distension or a separation of the mass, provided, of course, that an excessive amount of air is not present to begin with. In such a case, reworking avails but little.

While the occluded air in a satisfactory state of diffusion does not affect the normal diameter of the pores or channels, its presence is nevertheless a source of weakness; hence the shortness of much pugged clays.

If the clay be of the coarse granular type, one which offers a maximum resistance to its passage through the machine, the more efficient pugging

thus obtained may be sufficient to diffuse the air and destroy the initially formed structure during a single passage through the machine. In this type much pugging does not cause the same comparative loss in plasticity. This is due to the fact that these clays contain more of the water-filled void spaces, which offer lodgment to a greater portion of the air at points where its weakening influence is at a minimum. Thus if the quantity of air present in the beginning is only sufficient to displace the filler water, then intensive working under pressure would effect an actual cure. Otherwise, we would have, at best, a distribution of the weakening influence throughout the mass.

Auger lamination is due to that air which has been set free by the friction between the auger surfaces and the clay. This air collects at the tips of the vanes and its only avenue of escape lies between and with the clay-streams moving toward the die. A situation of the same character obtains at core-bridges, causing core-bridge lamination. Repress lamination is caused by air which is in part set free in the breaking apart of the mass and partly by the movement of one section upon the other while under pressure in the mold.

The layers of free air besides acting as walls which prevent the clay from uniting also act as lubricants which are largely responsible for any differential flow as well as affecting the efficiency of the auger.

The swelling of the clay bar as it comes from the die is due to the re-expansion of the inclosed air.

Tempered clays free from air slake very slowly, while those through which air has been thoroughly diffused slake rapidly, requiring only minutes as against weeks or months as in airless clays. If the air has been less thoroughly diffused, the mass falls apart rapidly, but the resulting units, being airless, slake slowly.

In the experiment with the hollow-ware machine, the air was given an opportunity to escape from that portion of the clay which was left in the throat of the machine. Being airless it did not laminate, neither did it slake rapidly.

Incorporated air affects the drying qualities of clays in at least three different ways. First, its presence lowers the strength of the mass-making it impossible for the attractive forces to move as great a load without causing a separation as would be otherwise possible. Second, the air in any state of diffusion may sufficiently expand under the heat of the dryer to cause ruptures. This is probably a common cause for breakage among the feebly plastic types. Such a clay was the one referred to which cracked in saturated atmospheres at comparatively low temperatures. Third, and perhaps the most common cause, is the hindrance which the air blebs offer to the ready egress of the water. In this too, the inevitable expansion of the gases due to dryer temperatures adds to the difficulties. For to

entirely obviate the losses from this source, it is not alone sufficient to bring the blebs to such a size which will permit their ready escape to the surface at normal temperatures, but due allowance must also be made for the expansion.

It is evident that after the air has been broken up into blebs by intensive working, in the molding machine, to such a size as may be contained in the pores without exerting a pressure at the lower temperatures, compensation for the higher temperatures becomes increasingly difficult, if not wholly impossible from a practical standpoint.

Assuming that the blebs are unable to assume a spherical form in the narrower sections of the channels, as soon as drainage conditions are established they will move until they reach the water-filled void spaces where they are afforded a better opportunity to form into spheres. If the resulting bubble is only large enough to displace the filler water, it can not effect the drying quality of the mass. But if it also displaces a part or all of the surrounding water of moldability, it becomes an obstruction by narrowing or entirely closing the channel except for the thin film of capillary water, which must then assume the burden of supplying the water to the surface. Not being equal to the task, the outer portion of the mass dries and the piece cracks.

It is evident that after the blebs have come to the spherical form in the wider portions of the channels, they can not be dislodged unless they be again elongated to allow their passage through the narrower sections. Since the force available for this purpose is practically nil, the blebs remain as barriers until the water between them and the surface has been removed.

Thus it seems that the presence of air offers a very satisfactory basis for explaining the peculiar behaviors of the various clays. The removal of the air from clays prior to and during the tempering and pugging process which has been made subject of Letters Patent offers great possibilities not only in improved products in clays now worked, but also in the utilization of many broad acres of clay, which though well situated with reference to markets has hitherto been unavailable because of the difficulties attending their manufacture.

J. J. Fred Brand
Roseville, Ohio

Discussions

By W. D. Richardson:—The paper presents a close study of a subject in which all brick manufacturers are interested and of which we all need to know more.

The treatment is a valuable contribution and creditable to the author. Even in reading his paper one becomes, as he states he was in his investigations, "engulfed in a series of complications." This comes somewhat

from the fact that the conditions and movements inside of an auger machine between the end of the auger and the mouth of the die must be imagined, as they can not be seen.

The whole subject is one that should be given such a thorough systematic investigation, with a variety of clays, as is practically impossible by a brick manufacturer himself, and his experience must necessarily be limited to the clays with which he has to deal.

The matter should be referred to our Research Council for further study and investigation.

A radical statement in this paper is that differential lamination is not caused by differential flow, and that the center of the mass of clay in the nozzle of an auger machine does not move faster than the center though this statement conflicts with a later one.

This statement does not conform to general observations of practical men. Whether the differential flow is due to difference in the friction between the clay and the iron and between the clay sliding on itself or to the greater pressure exerted by the auger on the center of the clay mass, it has been generally observed that the central portion of the clay does forge ahead of the sides, and it is generally believed that this is the primary cause of differential lamination.

The author thinks he has proved his point by the fact that when the barrel lining of the machine becomes worn smooth the clay will turn or float with the auger. But this is not logical, since it leaves out of consideration the compressive force of the auger on the clay in front of the auger.

Another radical statement in the paper is that auger lamination is not caused or influenced by the helical rings of clay passing off of the ends of the auger being polished or slicked by the surface of the auger or at least that this slicking is not a primary cause of these rings of clay not uniting thoroughly in the die. It is fair to assume, however, that the author would admit that this slicking, which is more pronounced in fine-grained plastic clays, prevents the escape of the air between these surfaces and thereby prevents their bonding together.

Undoubtedly, occluded air does prevent the bonding of clays in a strong homogeneous body and is a cause of blisters or laminations, of spalling or perhaps dunting, as hand molders of glass pots or blocks or other clay bodies well know.[1]

Mr. Brand's studies on the effect of air in clays in producing lamination and cracking in drying are the most valuable part of his contribution and he should be induced to write a paper on this theme alone giving a more detailed account of his experiments, with photographs or drawings of the apparatus employed, citing also the patents that he refers to and showing whether any of these are of practical application in brick manufacture.

[1] Simcoe, *Trans. Am. Ceram. Soc.*, **11**, 343 (1909); **12**, 376 (1910).

REPLY BY J. J. FRED BRAND:—But for the presence of air within the clay mass, differential flow would not cause differential lamination. Differential flow, however, is a factor and without *it* there would be no differential lamination. We can see that in many of the hand-made soft mud bricks which show, upon breaking, pockets and holes which undoubtedly contained air at the time of molding, but because of the fact that there is practically no differential flow during the molding process these do not become flattened out as in auger machines.

The impression I wanted to leave was that differential lamination was due not so much to the differential flow arising from the forging ahead of the center portions of the column, as to the differential twisting which obtains between the auger and die. For most part the secondary differential, which obtains as the clay enters and passes through the die, little more than modifies the shape of clay layers formed near the auger. Clay does not slip on itself with greater ease than upon a lubricated die. Any forging ahead of the center portions of the column is rather due to the cushion of air between the layers of clay. Ordinarily there is a forging ahead of the center, but Figs. 4 and 5 show that this is not always the case.

When the barrel of an auger machine becomes worn smooth there is a serious loss in capacity. This is due to the fact the clay in the auger turns with the auger instead of moving forward. The corrugations in a new lining do not at all come into contact with the moving clay, except at the tips of the corrugations perhaps, which the auger may touch and keep clean. The thing which prevents the moving clay from turning with the auger is the clay plastered lining. Admitting, however, that the clay nearest the corrugated lining does move forward instead of acting as a plastered surface, even that would not show that clay slipped on itself easier than upon metal. For if it did, a break would certainly occur in the clay which is between the auger and lining (augers never fit closely) and the two surfaces would slip on themselves.

The auger does slick the clay ribbons of the auger, but the differential twisting which obtains in the throat of the machine destroys these slick surfaces. In the fine-grained clays we have less of the filler or pore water than in the grogged or naturally coarse clays, hence the air can not lose itself in the spaces occupied by this water to the extent as in the latter. It must then displace water of moldability which causes a separation of the mass. In other words, if there is enough filler water space in the mass to carry the occluded air and means at hand for diffusing the air into these spaces we do not have a separation of the mass in the way of laminations.

One can not of course see the clay on its way through the machine but by adding foreign materials to the clay (the writer used oats) and then stopping the machine when full of clay, he can follow very closely the course of

the clay through the machine. The oat grains arrange themselves parallel to the direction taken by the clay with the base of the grain ahead.

By E. Lovejoy:—Mr. Brand gives us new names for lamination, namely, differential and interfacial, the one caused by slippage of the clay on itself, commonly termed die lamination, and the other a junction of cut masses of clay, which we are accustomed to call auger lamination. He includes in the latter term the union of surfaces cut by core-bridges which is not consistent with the meaning of the word lamination. The auger lamination is distinctly a union of cut surfaces and may be called interfacial, but with it there is some differential flow which develops the cone in cone structure. I am inclined to stick to the old terms. The repress lamination is not clear to me. We have always assumed that the effect of repressing was simply to buckle and separate the machine laminae. We never recognized any lamination in pressing stiff-mud shaped bricks, the mud for which was batted out by hand.

If I understand his statement in regard to the water content in pugged clay, I can not fully agree with him. A granular clay will take less water in pugging than a colloidal clay, but in the flow through the die one can not determine the rate from the water content. The character of the clay in its adhesive and cohesive properties is a big factor in the flow, considering the movement of the mass from the back of the machine to and through the die. The strongly adhesive, and correspondingly weak cohesive clays will be more difficult and flow at a slower rate then the clay of a contrary character.

I agree with him that in every instance there is more or less rotation of the mass of clay with the auger and I have experienced the effect of a smooth barrel as he suggests, and had the greatly reduced output in consequence.

I have illustrated this by a bolt and nut. Turning the bolt will not advance the nut, instead the nut turns with the bolt, but if the nut is held and prevented from turning, it will be advanced in turning the bolt. Similarly if the clay slips easily in the barrel of the machine it will turn with the auger and not advance through the die. One might conclude from this that the adhesive clays would be more favorable to flow than the cohesive clays, contrary to the statement above given, but not so, because there is always a clay lining in the barrel and it is the clay slipping on itself that causes the turning with the auger. We get adhesiveness by corrugations in the barrel.

The usual simple explanation of auger lamination is that the auger cuts the mass of clay spirally and packs these spiral slices into the die and they are drawn out into the cone in cone structure by differential flow. This is good enough for me, but I accept the very likely possibility that a firm union of these slices may be prevented by air.

Mr. Brand rejects the common conception of die lamination—that is, differential flow in consequence of die friction, but it is not clear to me that he offers any other explanation.

In pugging, I agree with him that increased pugging does not lessen lamination. It does develop the inherent qualities of the clay that result in a stronger and better formed ware and this is the purpose of wet-pan preparation and not the reduction of lamination.

The soak pit tempering which he belittles is, in my opinion, superior to our modern rapid and continuous machine preparation. The general abandonment of its use is due to its inadequacy in modern operation instead of lack of preparation.

Grog, as he states, is successful in lessening lamination, but he rejects the usual belief that the effect of grog is to prevent slippage of the clay on itself, and in this I can not concur. Grog not only reduces the slippage but also roughens the surfaces of the laminae and thus increases the possibilities of a firm union, besides serving as binders to hold the planes from separating under drying shrinkage strains.

The main feature of Mr. Brand's discussion is the effect of included air on lamination, and I agree with him that it may play an important part in this serious trouble. That the wet clay mass contains air is beyond question. Perhaps all of us are familiar with the air blisters on the surface of machine clay columns, and with the various attempts to overcome the trouble by cutting knives, gratings, etc. A number of years ago several such devices were introduced as a cure for lamination and in some degree with some clays they were effective. The idea was that such contrivances between the auger and the die served to equalize the flow of the clay, but we would still have the "interfacial" lamination which if not strongly united would be as bad as the ordinary lamination, nor could the devices eliminate the unequal flow in consequence of the friction of the die.

However that may be they did improve the product in a number of instances, but extended use showed that the effect in any consequence was limited to a few clays, and the devices fell into disuse. It is likely that the value of the devices was in shredding the clay in the machine barrel and thus permitting the escape of some of the air. With all, or part, of the air removed, the chances of slippage would be less and those of union of the split masses greater.

That included air could easily act as a lubricant to increase the slippage of the clay and prevent the planes from re-uniting is unquestionable, and this part of Mr. Brand's discussion is worthy of serious consideration by the clay workers of the country, who are concerned with the means of overcoming the trouble, and not with the technical data and theories in explanation of the movement of the clay through the machine and die.

REPLY BY J. J. FRED BRAND:—Ordinarily perhaps the repress does merely buckle and separate the machine laminae, in fact the brick would naturally go to pieces along the lines of greatest weakness, especially if the line of weakness coincided with the plane which would be produced in the mold. If a clot of clay full of occluded air is placed in a repress mold which it does not fit too closely, a differential lamination will be produced on account of the differential flow which would obtain during pressure. I once saw a plunger machine making fire-clay shapes measuring about 8″ x 8″ out of a very coarse clay. The bar from the machine, due to the absence of an auger and high pressure, was such that one would say that there was no lamination. Yet when these came from the repress they were laminated badly. The product of the die because of its excellent structure would never have given a hint of what would happen to it in the repress. The horizontal cracks obtained in ware from the dry press at times are certainly a type of lamination due to air.

Mr. Lovejoy's adhesive and cohesive properties of clays are not clear to me, but it seems taking an extreme case, as a so-called colloidal clay would flow through a machine with greater ease than a clayey sand as the other extreme.

The corrugations of an auger barrel always become clay plastered, that is, the moving clay never comes into contact with the corrugations except, perhaps, at the extreme tips. This clay plaster is the thing which prevents the clay from turning with the auger. I say, prevents, this of course is not strictly true, because the clay does turn with the auger to some extent. It, however, is the best thing we have to prevent it.

It has been my observation that the greater part of differential lamination is formed at the face of the auger by the differential twist which obtains there; the pushing ahead of the center portion of the column mostly giving a new form to the laminations already produced. However, there are too many factors involved to say that this is exactly what always happens.

Grog increases pore space or filler water space, which permits air to escape into it and here it cannot cause a separation of the mass. It also increases the friction of the clay in the forming members, and with it increases differential rotation which in turn aids in the diffusion of the air into these pore spaces, resulting in lessened lamination.

Undoubtedly the cutting knives, gratings, etc., which Mr. Lovejoy mentions merely serve to increase friction and with it a better diffusion of the air through the clay mass.

BY R. A. HORNING:—Mr. Brand has brought forward many interesting things concerning lamination. I know of nothing of more importance to the Heavy Clay Products industry than some constructive research on moist clay.

Mr. Brand's ideas on the cause of most lamination have been well founded if he has gone through this as well as his paper indicates.

It will be interesting to note just what will come from Mr. Brand's new thought on the cause of lamination and just what methods will be applied to make it practicable.

By George W. Shoemaker:—I have carefully studied Mr. Brand's paper and have checked his findings against the conditions existing in our machines and our clay column.

His observations and samples can be duplicated in kind if not in degree at our No. 1 plant.

I would comment on his paper as follows:

His observations as to the forms of the lamination in the clay, at the various stages of its passage through the machine, are correct.

These observations tend strongly to establish a basis for his theory of lamination.

It would be worth while for some one with laboratory facilities to try pugging clay in a closed pug directly connected with an auger machine and using low pressure steam instead of water. The writer believes that the proposition of excluding the air by the use of steam is more feasible than that of exhausting the air by means of a vacuum.

PAINTING IN UNDERGLAZE COLORS ON THE BISCUIT

By Frederick H. Rhead

ABSTRACT

This paper describes the more commonly known underglaze colors and gives typical formulae.

The commercial colors on the market are recommended for general use.

The various bodies suitable for this process, white or colored, are described, and the more generally used mediums with methods of preparation are given. The different methods of application and decorative treatment are discussed in connection with both transparent and opaque colors. Comparisons of the technique are made between underglaze painting and oil and water color painting.

Glazing and firing treatment is also discussed. The paper concludes with some notes on historical types.

Underglaze Colors and Their Composition

Underglaze colors are finely ground calcinations of the various metallic oxides together with such materials as alumina, flint, zinc, whiting, etc.

The degree of heat necessary for calcination is determined by the type of color and its composition. For instance, a blue for comparatively low temperature work (cones 1–4) and consisting chiefly of cobalt and zinc need not be calcined to the higher temperature necessary for a cobalt-alumina blue to be used to cones 12 to 18.

As a general rule, in present practice, more brilliant colors are available for temperatures ranging below cone 6. At higher temperatures, especially when exceeding cone 12, blues, greens, grays and blacks seem to predominate, although it is possible to produce clear pinks, crimsons, yellows, lilacs and browns at temperatures ranging from cones 14 to 18 and higher.

Having a suitable formula, the two essentials in the making of reliable underglaze colors are, (1) correct temperature and atmospherical conditions for the calcination, and (2) the extremely fine grinding of the final mixture. It is difficult to state which is the more important of these two. Any variation in the calcining or grinding will result in variation in color and texture. As each color requires an individual treatment it is no simple matter to prepare a wide range palette satisfactory to the decorator. This is why one color manufacturer specializes in pinks and crimsons, another in blacks, another in blues, and so on. Also, as the glaze is an important factor, a certain make of color highly valued by one decorator will not give the same satisfaction to a painter using a different body and glaze.

The following formulae will give an approximate idea of the compositions of underglaze colors used in present commercial practice (Table I). The mixtures are usually sieved dry two or three times, calcined and afterwards well washed and ground. In this discussion, we are not concerned with the actual process of color making. This subject will be dealt with in a future paper.

TABLE I

UNDERGLAZE COLORS

	Blue	Pink	French green	Black	Brown	Yellow	Orange	White	Olive-green
Tin	..	40	..	20	..	30	30	48	..
Whiting	40	15	..	..	..	..	..	..	..
Fluorspar	..	6	..	..	..	..	..	..	..
Flint	..	16	75	..	..	..	..	..	50
Bichromate of Potash	..	2	..	..	..	..	..	..	..
Zinc Oxide	..	..	25	..	40	..	..	..	20
Borax	..	..	100	..	..	..	..	60	25
Ox. Chrome	..	..	20	..	6	..	..	..	30
Ox. Cobalt	150	..	10	50	..	..	..	..	10
Ferric Oxide	..	..	..	10	6	..	35	..	..
Ox. Nickel	..	..	..	20	..	..	..	..	..
Red Lead	10	..	..	..	5	90	100	60	..
Flint Glass	40	..	..	..	..	..	..	..	..
Nitrate Potash	10	..	..	..	..	..	..	..	..
Chromate Iron	..	..	..	120	..	..	..	..	..
Boracic Acid	..	..	..	..	5	..	..	..	..
Antimony Ox	..	..	..	..	..	60	70	..	..
Feldspar	..	..	..	..	..	..	..	100	..
Lynn Sand	..	..	..	3	..	..	..	10	..
Carb. of Soda	..	..	..	..	..	..	..	..	..

TABLE II

LIQUID UNDERGLAZE COLORS

	Tur-quoise	Light blue	Dark blue	Green	Dark green	Yellow	Brown	Gray	Pink-gray	Gray-black
Water	100	100	100	100	100	100	100	100	100	100
Glycerin	50	50	100	100	..	100	100	100	50	50
Nitrate copper	30	..	..	50	..	..	..	..	..	..
Nitrate cobalt	..	25	40	..	..	..	..	..	..	..
Nitrate uranium	..	..	..	..	..	100	..	..	..	..
Chromic acid	..	..	..	..	80	..	..	..	..	..
Ferric chloride	..	..	..	..	..	..	100	..	..	
Nitrate nickel	..	..	..	..	..	..	..	120	..	..
Chloride gold	..	..	..	..	..	..	..	..	40	..
Chloride platinum	..	..	..	..	..	..	..	..	..	40

When assembling an underglaze palette, small brush trials should be made showing the colors in light and heavy washes. When the trials come from the kiln, the various stains of same color are compared. Attention should be given to texture as well as color value. Certain colors may be too highly fluxed for some purposes, resulting in flowing and softening at the edges of the wash, or they may be absorbed into the glaze. In some cases this softened effect may be desirable, but its effect must be noted in comparison with the texture of the remaining colors in the palette. For the preliminary palette, it will be wise to select those colors which are clear and firm.

While this discussion is concerned with powder colors, in underglaze work, there is another type of color used to some extent in the decoration of porcelain, and to a lesser extent in faience and terra cotta work. These colors are liquid in form and are solutions of nitrates and chlorides. Typical formulae are as shown in Table II.

These colors are most valuable when flat washes of low tones are desired.

Types of Biscuit Bodies Suitable for Underglaze Decorations

Underglaze colors may be successfully applied to any type of biscuited or baked body, although white, cream, buff and sometimes red bodies are more generally used. If a proper medium is used, it makes little difference whether the body is porous or vitrified.

With few exceptions (the matte blues, light yellows, deep chrome greens, and certain browns) underglaze colors are more or less transparent. Consequently when darker bodies are used, it is advisable to add underglaze white to the colors much as one uses white in oil painting. Or, a ground consisting of white alone, or mixed with some other color may be brushed, sprayed or sponged over the surface, and the decoration applied over this.

Painting Mediums

1. Water.—If the body is porous, the colors may be ground in water to a thick paste and used much as one would use water colors. This method is only suitable for direct painting, and considerable skill is necessary if elaborate decorations are required. There is also the danger of rubbing the decoration which will powder at the slightest touch before it is glazed. If the body is very porous, considerable water must be taken up in the brush, in fact the process in this case is like painting on blotting paper. The two chief advantages in using water alone as a medium are, (*a*) it is simple and suitable for direct painting, (*b*) the work can be glazed without an extra firing before the glaze is applied.

2. Gum Arabic.—A twenty-five per cent solution of gum arabic with water, and possibly a little glycerine makes a satisfactory painting medium. If too much gum is used there is a possibility that the color or glaze may

blister, even if the finished work is fired or "hardened on" before glazing. It is advisable to make preliminary tests before doing elaborate work with this medium. When gum arabic is used it is possible to do more delicate and finished work than when water alone is used. It is also possible to paint over a wash or background without disturbing the wash underneath.

3. **Glycerine.**—The colors are ground in glycerine alone, or in fifty parts glycerine and fifty parts water. More glycerine is used when the body is very porous. This medium is probably most useful for general purposes. Either direct painting, flat wash work, or a highly finished technique is possible with glycerine, and it is not necessary to fire the work before glazing.

4. **Turpentine and Fat Oil of Turpentine.**—These two mediums have been in general use both in purely commercial work and by artists specializing in underglaze painting. The colors may be applied quite heavily without danger of peeling or blistering. But it is necessary to fire the ware to a dull red before glazing, in order to burn out the oils.

All the given mediums have been used successfully by highly skilled painters and by decorators working on large-scale production. The choice of medium is simply a question of technique, and suitability to existing conditions at hand.

Hardening on Process

This is the preliminary burning to a dull red heat of the decorated wares before glazing. It is only necessary when the turpentine and fat oil mediums are used, although it may be advisable when much gum arabic is used.

Use of Underglaze White

White is not necessary in work involving white or light-colored bodies, although it is often used effectively either as an opacifer, or in painting lighter colors over darker shades. It is mixed in with the colors as Chinese White is mixed in water colors, and as Flake White in oil colors.

When red or other dark-colored bodies or grounds are required, white is almost an essential, especially when clear light colors are wanted.

Preparation of Surface for Painting

For ordinary purposes little preparation is necessary. It is enough to see that the surface is clean and smooth, and free from grease. A rough biscuit surface can be sand-papered if a very smooth surface is desired. If the surface is too porous, a wash or spray of the same medium used in the painting process may be applied. Many painters rub or brush the painting medium into the bisque surface much as a painter will prepare his canvas. Some painters brush a flux or glaze over the surface. This helps to soften and bind the colors.

Brushes.—The type of brush obviously depends on the technique of the painter, and the class of work under consideration. The only essential is that it be of the best quality. Red or brown sable pointed brushes are suitable for general work in all the mediums. For outlining, ox hair writers are most satisfactory. If large decorative work requiring an oil color technique is to be done, regular oil color bristle brushes are most suitable, but this type of brush can only be used when turpentine and fat oil are the mediums.

Liquid Underglaze Colors

As stated these colors are only suitable for flat decorations. A particular color will give just one value or tone no matter how heavily or frequently the wash is applied unless the ware is subjected to a red heat firing before the second coat is applied. If the ware is soft and porous, the color will spread over the surface. As the nitrates are more or less colorless until they are fired, it is advisable to mark with a lead pencil those surfaces which have been covered. Better results will be obtained if the design is first outlined with a vegetable lamp black using glycerine or fat oil for a medium. This outline will burn away, leaving a white outline. If colored outlines are wanted underglaze colors may be used instead of the vegetable black.

Wares decorated with these liquid colors should be hardened on before they are glazed. The colors oxidize and develop when they are burned to a red heat, and it is possible to make needed corrections before the piece is glazed.

Glazing and Firing

The conditions surrounding these two processes must be very carefully considered. Before any important work is attempted, experiments on medium, glazing and firing should be made. Some colors, the cobalt blues, for instance, develop and are stronger in tone after the ware is fired. Browns, some yellows and greens appear considerably lighter than when applied. The chemical composition of the colors must also be reckoned with. For instance, if an iron-yellow is mixed with a chrome-green the result will not be a yellow-green but a strong brown.

Also, if a tin-white is used with greens containing chrome the result will be pinks and crimsons instead of the lighter and colder greens of the oil color palette. Preliminary trials will determine what mixtures may be safely used. A decoration in underglaze color may have to be painted to appear hard and crude before it is fired to allow for chemical adjustments during the period of firing.

The method of glazing must be considered before the piece is decorated. If the piece is a vase, and water or glycerine is the medium, it will be wise

to glaze the inside of the piece before the decoration is applied. This can be done by pouring liquid glaze in the piece and turning it round until the inside surface is covered. The remainder is then poured out.

Unless a flowing effect is desired, only those glazes which do not run should be used. Both matte and glossy glazes may be used providing the applied coat is not so heavy that there will be flow enough to disturb the design. The glazes may be white or colored. If colored, the influence of the glaze on the applied decoration must also be reckoned with. A yellow glaze will change the blues to greens. A manganese glaze will make blue appear purple.

Unless the decoration is on a flat surface, as in tile, care must be taken not to have too heavy a coat of glaze because a slightly too high firing temperature will cause the flowing of the glaze and the running of the colors in the decoration. In making the preliminary trials, the thickness of the glaze coat should be noted, and judgment exercised accordingly when the finished work is being glazed.

Suitable Bodies and Glazes for Underglaze Work

As stated, almost every type of body is suitable for underglaze work. The only condition to bear in mind is that concerned with the use of white in the colors when dark bodies are being decorated. Table III shows white

TABLE III

WHITE TRANSPARENT GLAZES

	White Transparent 03–		White Transparent 1–3		White Transparent Cone 8–10
White Lead	330	White Lead	185	Cornwall Stone	240
Feldspar	160	Feldspar	55	Feldspar	240
Flint	175	Flint	35	Flint	225
Whiting	45	Whiting	12	Whiting	150
China Clay	8	China Clay	...	China Clay	50
Zinc Oxide	14	Zinc Oxide	10	Zinc Oxide	40
Barium Carbonate	5	Cornwall Stone	55	Barium Carbonate	17
Ground Glass	200			Ground Glass	60
Borax	15			Borax	5
				Tin Oxide	10

glazes which have been found suitable for underglaze work. If colored glazes are required, the formulas given can be stained in the usual manner, copper for green, uranium or iron for yellow, manganese for brown, cobalt for blue, and combinations of these according to the color desired.

Some Historical Types

Of the many kinds of wares decorated with underglaze colors, the blue and white wares are possibly the best known. The Ming, K'ang-hsi,

Yung-Cheng and Ch'ien-ling blue and white porcelains are known for their exquisite delicacy and finish, and have been the inspiration for about all the blue and white decorations that have been produced since.

The Persians have used underglaze colors, but generally in connection with colored glazes. In some instances the outline only would be in a crude underglaze color, and the spaces filled in with colored glazes, or a certain part of the decoration would be executed in U. G. colors, and the remainder in colored glazes. The French potters, Deck, and a number of the faience manufacturers have done considerable work in this process. They employed, and now employ painters and decorators of considerable reputation. These artists execute elaborate paintings of figures, landscapes, and exquisitely painted flowers. Some of these works consist of tile panels often ten or twelve feet or more in size.

Mintons of England have perhaps produced a greater variety of underglaze decorations than any other one organization. They had a large force of artists who were specialists in different classes of decorative work, and who painted figures, landscapes, flowers, animals, fish, and conventional decorations on earthenware and porcelain in white and colored bodies.

The Staffordshire printed underglaze decorations are well known, and need little comment.

On the continent, we have the Rozenburg pottery in Holland where rich and highly colored conventional decorations are executed on porcelain, and on a beautiful light terra cotta body. Both tile and ornamental wares are made by this concern. The Copenhagen pottery in Denmark use underglaze processes almost exclusively. The Rorstrand pottery in Sweden also does underglaze work on porcelain of a similar type to that made by the Copenhagen organization.

A large number of individual potters and commercial organizations in Germany are doing underglaze work but to date this process has not been used to a considerable extent in this country, except perhaps in Mexico where decorations showing an Oriental, Spanish and Italian influence are quite common.

It should be hardly necessary to state that there are great commercial and artistic possibilities in the use of underglaze work on the biscuit. Here is a rich and varied palette for the painter who possesses the necessary technique for either oil or water color painting, and in addition it can be used for the mechanical printing processes which, unfortunately, are now almost entirely discarded for the decalcomania decorations. This country possesses many remarkable draftsmen who could design such decorations for printed wares as have not yet been done. We all know how much the Staffordshire printed wares have been sought by collectors after they have enjoyed some thirty years' commercial vogue. It is easily

possible that some enterprising manufacturer may commission a draftsman of the reputation and skill of Joseph Pennell or any one of a hundred others to design a series of decorations for utilitarian ware or tile. I think that the commercial and artistic possibilities for the printing process in underglaze colors are so great that it is bound to be revived.

In these references to underglaze decoration, I have not considered the slip or those other processes where underglaze colors are used either on a clay surface or over unfired glazes. These calcinations have many uses other than their connection with painting over a biscuit surface. They are used for both body and glaze stains, and they also form the coloring agent for the slip processes. These, however, will be dealt with in future papers.

Discussion

By Mary G Sheerer:—In addition to what Mr. Rhead has told us in his very interesting paper, I should like to speak of the method of "Preparing the Surface for Painting" in use at the Newcomb Pottery in New Orleans. The body is sponged very thoroughly in the "green" or unfired state to give it the required "tooth" to receive the washes of color after the first-fire, or on the biscuit.

Large flat hair-brushes are used to put on the flat washes with water as a medium. The values are controlled by adding more color with a smaller brush or by removing it with an eraser or stiff brush. It has also been found important to fire the biscuit lightly so it will not only take the washes more readily but that it may be glazed easily by dipping. If the biscuit were fired harder the glaze could not be handled without disturbing the painting or without a "hardening-on" fire.

Gum tragacanth, carefully sifted, is used with the color.

JOURNAL AMERICAN CERAMIC SOCIETY

Preparation of Abstracts

Every article in THIS JOURNAL is to be preceded by an abstract prepared by the author and submitted by him with the manuscript. The abstract is intended to serve as an aid to the reader by furnishing an index and brief summary or preliminary survey of the contents of the article; it should be suitable for reprinting in an abstract journal so as to make a reabstracting of the article unnecessary. The abstract should, therefore, **summarize all new information completely and precisely.** Furthermore, in order to enable a reader to tell at a glance what the article is about and to enable an efficient index of its subject matter to be readily prepared, the abstract should contain **a set of subtitles** which together form a **complete and precise** index of the information contained in the article. This requires at least one and often several subtitles even for a short abstract.

In the preparation of abstracts, authors should be guided by the following rules, which are illustrated by the abstracts in THIS JOURNAL for February and March, 1921.* The **new information** contained in an article should first be determined by a careful analysis; then the subtitles should be formulated; and finally the text should be written and checked.

Rules

1. **Material not new** need not be analyzed or described in detail; a valuable summary of a previous work, however, should be noted with a statement indicating its nature and scope.

2. **The subtitles should together include all the new information;** that is every measurement, observation, method, improvement, suggestion and theory which is presented by the author as new and of value in itself.

3. **Each subtitle should describe the corresponding information so precisely** that the chance of any investigator being misled into thinking the article contains the particular information he desires when it does not, or vice-versa, may be small Such a title as "A note on blue glass," for example, is evidently too indefinite a description of information regarding "Absorption spectra of glass containing various amounts of copper-cobalt and chromium-cobalt." General subtitles, such as "Purpose" and "Results" should not be employed as they do not help to describe the specific information given in the article.

4. **The text should summarize the authors' conclusions and should transcribe numerical results of general interest,** including those that might be looked for in a table of physical and chemical constants, with an indication of the accuracy of each. It should give all the information that anyone, not a specialist in the particular field involved, might care to have in his note book.

5. **The text should be divided into as many paragraphs as** there are distinct subjects concerning which information is given, but no more than necessary. All parts of subtitles may be scattered through the text but the subject of each paragraph, however short, must be indicated at the beginning.

6. **Complete sentences** should be used except in the case of subtitles. The abstract should be made as readable as the necessary brevity will permit.

7. **The ms. of all abstracts must be typewritten and double or triple spaced.**

* The rules were prepared by the Research Information Service of the National Research Council. The Society is indebted to Dr. G. S. Fulcher of the Corning Glass Works (formerly with the National Research Council) for the rules and the illustrative abstracts.

CERAMIC ABSTRACTS

Compiled by the

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General and Miscellaneous

1. Graphical treatment of stack gas analysis and fuel gas analysis. W. TRINKS. *Blast Furnace & Steel Plant*, **10**, 50–58(1922).—Charts calcd. for stack gas analysis, natural gas, by-product tar, coke-oven gas and for coal gas are based upon Walter Ostwald's "*Beitrage zur graphischen Feurungstechnik*" and upon similar papers which have appeared in German scientific journals. (Cf. *C. A.*, **14**, 257, 484, 490, 2414, 3552, 3569.) W. T. HALL (*C. A.*)

2. Pulverizing anthracite coal. HARLOWE HARDINGE. *Elec. World*, **79**, 433(1922).—Anthracite culm with an ash content of 25 to 30%, considered to be the hardest anthracite in the eastern U. S., was ground in a mill so as to allow 90% to pass a 200-mesh screen. The power required for grinding amounted to 30 h. p. hrs. per ton of coal. A softer coal with 18% ash required a total of 20 h. p. hrs. per ton ground to 200-mesh, 90%. C. G. F. (*C. A.*)

3. Heat utilization and economy in steam power plants. W. GRAULICH. *Chem.-Ztg.*, **45**, 1233–38(1921).—An elementary presentation of the principles of combustion, and heat utilization in boilers and engines, intended primarily to assist owners and operators of small power plants in effecting economies by the use of modern devices and methods. Numerical problems on heating value of fuel, boiler and engine efficiency, satd. and superheated steam, waste steam and flue gas utilization, are given in detail. W. C. EBAUGH (*C. A.*)

4. The "Gee-system," a new procedure for the separation of solid materials from liquids. C. R. PLATZMANN. *Z. angew. Chem.*, **34**, Aufsatzteil, 623–35(1921).—This filtering system is a simple combination of the filter press and the centrifuge. Its advantages are: (1) const. flow coeff., (2) rapid filtration, (3) small space requirement, (4) no clogging up of the filter surfaces, (5) little wear on the filter cloths, (6) simple tending, (7) sepn. of the filtered out solids according to size of particles, (8) possibility of using high pressure, and (9) ease of assembling and taking apart. The construction and operation of the system are fully described with the aid of three drawings. The especial advantages of this system in the *elutriation of the porcelain clays* are: (1) it reduces the cost more than half, (2) it produces a much finer-grained product than was previously possible, (3) it gives a product of highest quality regardless of the phys. condition of the clay as mined, (4) the finest particles are recovered from the filtrate, and (5) the moisture content of the sepd. clays is lower than heretofore. Other applications in *ceramics* and in the *dye, paper, coal, brewing, malting and distilling industries* are pointed out. The system is in use in the kaolin industry in Cornwallis, England. C. C. VAN VOORHIS (*C. A.*)

5. Modernize coke-oven plants. J. M. HASTINGS, JR. *Iron Trade Rev.*, **70**, 262–66; *Blast Furnace & Steel Plant*, **10**, 12–17(1922).—The Rosedale and Franklin plants of the Cambria Steel Co. at Johnstown, Pa. constructed by the Semet-Solvay Co. are described. J. L. WILEY (*C. A.*)

6. Apply powdered coal to air furnace. P. DWYER. *Foundry*, **49**, 955–62(1921).—Malleable-Fe melting furnaces and annealing ovens have been converted from hand-firing to powdered coal firing without radical changes in design. At the Marion (Ind.)

Malleable Iron Works the annealing ovens can now be raised to the required temp. of 870° in 18 hr., where hand-firing took 72 hr. The powdered coal installation is described in detail. A. BUTTS (*C. A.*)

7. Contributions to the history of chemical arts. F. RATHGEN. *Chem.-Ztg.*, **45,** 1101–2(1921); 1 cut.—Descriptions and chem. analyses are given of (1) a Babylonian glass vase; (2) an antique Babylonian glass slab; (3) a silver ring from El-Armana; and (4) a sample of wool from a sarcophagus of the time of Alexander the Great, in which indigo was present as the coloring substance. T. F. BUEHRER (*C. A.*)

8. The utilization of liquid fuels in Hoffmann kilns. L. MASCARD. *Bull. soc. encour.*, **133,** 1192–95(1921).—The scarcity and expensiveness of coal in Oran (Algeria) led to the adoption of liquid fuels mixed with solid combustibles for firing Hoffmann kilns. The following methods are described: (1) Heavy petroleum fuel oils fed intermittently and by a continuous automatic process. (2) Mixts. of powdered coal and oil. (3) Mixts. of ground and screened coal cinders and smoke-box refuse with gas tar. This latter method was the most economical. In it combustion is less vigorous than with fuel oil, the fire is more easily regulated and more const.; this produces a red color in the bricks and tiles more easily. Greater fluidity of the gas tar enables the fuel to be handled easier. Better admixtures of the solid with the liquid fuel are maintained. Little or no soot is formed, and after 17 months' continuous operation less than 300 kg. was deposited. A. R. ALBOUZE (*C. A.*)

9. Kinetic and static coagulation measurements with suspensions. F.-V. v. HAHN. *Z. Elektrochem.*, **27,** 501–5(1921); cf. *C. A.*, **16,** 516.—The distinguishing characteristics of the different disperse systems are tabulated and discussed. Whether a sol belongs to the mol. system or not can be detd. by ascertaining whether it undergoes coagulation or flocculation. A kinetic method for coagulation measurements with suspensions is described. This method depends on weighing the sedimented suspensoid or detg. the d. of the dispersion medium over the sediment. Graphic representation of the results of coagulation measurements by this method shows that they agree with those obtained by the static method. H. JERMAIN CREIGHTON (*C. A.*)

10. Fuel economy. Excess air as a cause of waste. S. N. DUGUID. *Iron and Coal Trades Rev.*, **104,** 75–6(1922).—The principal losses in a boiler plant are estd. as follows: loss by handling 1%, in ash 3.9, radiation 2.9, incomplete combustion 0.7, excess air 19.6, faulty baffles 1.1, soot 3.8, scale 5.0, incorrect correlation of load and draft 3.8. D. shows how the loss due to excess air can be reduced and how efficiency can be increased by use of gas analyzers and CO_2 recorders. J. L. WILEY (*C. A.*)

11. Use of medium-grade gases in the steel industry. F. J. DENK. *Blast Furnace & Steel Plant*, **9,** 719–21(1921).—Natural gas, even with its high heating value, is not the best available gas to use in steel plant heating. The efficiency of a gas does not depend upon its heating value, but upon the flame temp., the amt. of air required for combustion, the sp. heat of the waste gases, and their quantity. For the above reasons coke-oven gas or Elliott gas, a combination coal and water gas made in the Elliott producer, is more efficient. The amt. of the latter made from 1 ton of coal varies between 57,000 and 63,000 cu. ft. with a heating value of 465 and 415 B.t.u. and the same sp. gr. as coke-oven gas. Comparative tests on open-hearth furnaces fired with producer gas of 143 B.t.u. and with coke-oven gas of 408 B.t.u. gave the following results: with the former 1 long ton of steel required 661.5 lb. of coal but only 11,477 cu. ft. of coke-oven gas; assuming a producer efficiency of 89%, the heat equiv. of the 2 fuels was 1414 B.t.u. for the former and 1000 for the latter, while the daily output was, resp., 39 and 49 tons. The av. life of a 30-ton furnace with coke-oven gas was 3.5 month with 10725 tons of steel, with producer gas 2.5 months and 8016 tons of steel. In a 100-ton furnace the respective tonnages per charge were 97.3 and 96.5 tons. In a 12-ton furnace

the respective daily production was 48 and 39 tons, the av. consumption of coke-oven gas being 9888 cu. ft. per ton. The advantages of using coke-oven or Elliott gas are: increased production, simplification in furnace construction, lower repair, initial and operating costs, and easier working of the charge. By applying Steck's formula for calcg. the relative value of the different gases, coke-oven gas is found to be 1.85 times and Elliott gas 2.21 times more efficient than producer gas. J. L. WILEY (*C. A.*)

12. A new incandescent burner for kerosene and heavy hydrocarbons. P. WAGUET. *Rev. prod. chim.*, **24,** 779–80(1921).—The fuel passes from the reservoir, through a wool filter and needle valve, into a pipe which rises close to the mantle, into a coil over the top of the mantle, then through a descending tube terminating in a fine opening, and finally through a tube like that of a Bunsen burner, which is curved to bring the vapors under the grating. To light the burner the reservoir is put under a pressure of about 1.5–2 kg. (about 20–27 lb. per in.^{2}) and a little alc. is burned to heat up the fuel in the tube beside the mantle and vaporize it. Various types of this burner have been designed for service under special conditions. For heating purposes the mantle is dispensed with, and the flame is that of a regular Bunsen. It is cheaper and safer than gasoline or compressed C_2H_2 burners. A. P.-C. (*C. A.*)

13. Gaseous firing for industrial purposes. F. J. BOSTOCK. *Gas. J.*, **156,** 882–84; *Gas World*, **75,** 573–5(1921).—For general purposes, the most economical method of using solid fuel is to subject it to destructive distn. The advantages of this are discussed. B. compares the methods of gaseous firing by low pressure, high pressure gas and air blast, and gas and air mixt. The latter method is the most practical soln. to the problem of gaseous firing. A special type of gas and air incorporator made in accordance with the Docking patents is described. It is capable of being automatically adjusted according to the quality of the gas and the temp. desired. Its application is broad and furthers economy in operation. The cost of gas for metal melting is compared to that of electricity. J. L. W. (*C. A.*)

14. Bentonite. R. B. LADOO. Bur. of Mines, *Repts. of Invest.*, No. **2289,** 5 pp.(1921).—Bentonite is a clay-like group of materials of rather indefinite compn. characterized by an easily replaceable alk. and alk. earth content of 5 to 10%, fine grain size, high absorptive power and colloidal properties. H_2O contg. $CaSO_4$ can be softened by passing through especially treated bentonite. It is utilized in the manuf. of *antiphlogistine* and other medical prepns.; as a retarder in the manuf. of gypsum wall plaster; as a *soap filler* as *paper filler* and as a *candy adulterant*. Its use in soap is not adulteration for it actually increases the lathering and detergent properties. Eight analyses of samples from different sources show ranges in compn. as follows: SiO_2 54.00 to 63.20, Al_2O_3 11.84 to 26.58, Fe_2O_3 2.46 to 3.97, CaO 0.59 to 4.94, MgO 1.01 to 3.24, K_2O 0.00 to 2.34 and Na_2O 0.66 to 4.33. D. B. DILL (*C. A.*)

15. Powdered fuel. J. S. ATKINSON. *Iron and Coal Trades Rev.*, **103,** 802(1921).—A description is given of a self-contained unit, called the *Turbo pulverizer*, which drys, pulverizes and feeds the coal to the furnace with the proper amt. of air for combustion. The installation has proved satisfactory, both with regard to furnace temp. and conditions, and to coal economy. In connection with a forge furnace the av. coal consumption for 6 mo. was 176 lb. per ton of metal; with a tube-heating furnace over 9 months, 4 cwt. per hr. for each 30 cwt. of metal. The av. cost for 300 days of coal pulverizing with a 1-ton per hr. installation was 2 s. 10 d. **The Turbo pulverizer** ANON. *Ibid.*, 877.—A description with diagram. J. L. WILEY (*C. A.*)

16. Pulverized coal as fuel. E. B. POWELL. *Elec. World*, **79,** 273–4(1922).—A brief survey. The utilization of waste fuels is emphasized. C. G. F. (*C. A.*)

17. Coal and coke mixtures as water-gas generator fuel. W. W. ODELL. Bur. of Mines, *Tech. Paper*, No. **284,** 32 pp.(1921); cf. *C. A.*, **15,** 1204.—Information is given

bearing on the effect of a stand-over period on capacity and possibilities in the use of the blow-run method of operating with mixed fuels, coal and coke. Data are included on the behavior of the various fuels used, the clinker conditions, the use of fuel high in ash and S. It was found that a decided benefit is realized when operating with a long lay-over period. When operating but a small part of the day, up to 8 hr., the capacity of the plant can be maintained in using 100% coal, but with the same vol. of air per min. per sq. ft. of grate area, the make per sq. ft. of grate per run hr. decreases markedly after that time until the hourly make is less than the normal make with coke. All bituminous coals do not behave the same and the method of operating should be worked out for each coal in order to obtain the best results. The size of fuel used is of importance and should be given more attention when using coal than when coke or mixed fuel. With coal blowholes form more often than with coke, especially when the coal is composed chiefly of large lumps and some slack. With mixed coal and coke no trouble appears unless the coal is in greater amts. than 60% by wt.; as % of coal increases the difficulty increases especially with high blast pressures and when no fuel spreader is used. The symptoms, cause and remedy for blowholes are discussed. The relative value of the air purge using coal, coke, and mixts. of each is shown and gas analyses are given. More benefit is to be derived from an air purge with coal fuel, or with coal and coke mixts., than with coke as the % of CH_4 and illuminants increase during the run and to a considerable extent neutralize the effect of the increasing % of CO_2. With mixed fuel, coal and coke: the tendency for caking and arching of the fuel in the generator is *nil* unless a high % of coal is used; the clinker troubles are not necessarily over those prevailing with coke alone; the fuel per M with blow-run operation is appreciably less than with 100% coal and the oil consumption is no higher; the capacity with blow-run operation is greater than can be obtained with 100% coal and may equal or surpass that with 100% coke; a more uniform gas standard can be obtained; trouble is less from tar emulsions, the tar settles out to about 1% H_2O; boiler fuel per M is no greater than with 100% coke. J. L. WILEY (*C. A.*)

18. Some critical observations on the generation of producer gas. J. GWOSDZ. *Brennstoff Chem.*, **2,** 345–6(1921); See *C. A.*, **15,** 3549.—Review of proposals to produce low-N gas by means of external heating. W. B. V. (*C. A.*)

19. Lean coals tested in gas producer. J. BLIZARD AND E. S. MALLOCH. Can. Dept. Mines, *Bull.* **33;** *Gas Age Record,* **49,** 135–6(1922).—An abstract of the results obtained with 25 Canadian lignites in a Westinghouse, double-zone, suction-gas producer. About ½ of the fuels tested can be recommended for continuous operation in this type of producer. The gas produced ranged from 51 to 106 cu. ft. per lb. of fuel, and from 75 to 120 B.t.u. The net B.t.u. efficiency ranged from 40 to 94. J. L. WILEY (*C. A.*)

20. Continuous water-gas producer. A. W. H. GRIEPE. *Am. Gas. J.*, **116,** 53–4 (1922).—The advantages over the intermittent type are: continuous flow and uniform quality of gas, clean gas and reduction in operating cost. The operation is as follows: In a producer shell is placed a hot plate heated by external gas burners. Steam from nozzles forces the powdered fuel and steam onto the hot plate, igniting the C and decomposing the steam into H_2 and O_2. Any grade of powdered coal can be used. The coal and steam are kept in the ratio of 2 to 3. The net amt. of gas produced from 1 lb. of C and 1.5 lb. of steam is 45 cu. ft. (18 cu. ft. are used for heating the plate). The gas compn. is: H_2 48.53%, Co 50.2, CH_4 0.785, O_2 0.015, CO_2 0.47, and 300 B.t.u. assuming 75% efficiency of the app. The cost per 1000 cu. ft. with coal at $5.50 per ton and water $1.00 per gal. is 12 cents. J. L. W. (*C. A.*)

21. Cleaning producer gas made from bituminous coal. H. W. SELDON. *Blast Furnace & Steel Plant,* **9,** 708–10(1921).—There is neither evidence nor sufficient reason

for cleaning producer gas except where it is absolutely necessary before the gas can be used for gas engine fuel or where the point of consumption is so far removed from the producer that deposits in the main cause trouble. All the known methods for cleaning sacrifice the sensible heat of the gas in addition to the B.t.u. value of the tar and volatile hydrocarbons. The combined loss is probably in excess of 20% of the heating value of the coal. It is calcd. that the sensible heat loss in cooling the gas to atm. temp. is equal to 11.6%. Thus it would be too costly from a fuel standpoint besides resulting in a gas unsuitable for the open-hearth furnace. J. L. WILEY (*C. A.*)

22. Using clean cold producer gas. C. F. KAUFMAN. *Iron Trade Rev.*, **70**, 267–70 (1922).—K. traces the development of the Smith glass-wool tar extractor and its use in connection with the Smith up-draft type of producer using bituminous coal or lignite as the fuel. The tar extractor consists of a mat of spun glass held firmly between 2 perforated plates and located in the gas line beyond the producer. A pressure of 2–3 lb. per sq. in. is necessary. It functions by collecting the tar fog into drops which are too heavy to be carried along by the gas stream and therefore are condensed and drain off. It has a cleaning efficiency of over 99.5%. It requires less power than mech. scrubbers, is much more efficient, and H_2O is not used in its operation, consequently no emulsions are formed, and the tar and H_2O in the gas can be sepd., the tar being returned to the producer for gasification. It is shown that illuminants in gas are not essential to furnace efficiency; therefore, the removal of them and the return of the tar to the producer to be gasified does away with the objection that the loss of B.t.u. value is detrimental to the heating quality of the gas and to efficient furnace operation. By this method the gas gains in quality owing to the increase in the H–CH_4 ratio and the CO content. Clean cold producer gas contains also a smaller amt. of S. The sensible heat is not wasted by cooling and cleaning the gas but is removed in the gas plant and taken up again in the regenerators in the furnace with a lowering of the stack temp. (Cf. Seldon, preceding abstract.) J. L. WILEY (*C. A.*)

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23. Gas manufacture. KOPPERS CO. Brit. 170,572, Oct. 6, 1921. Fuel gases, such as coke-oven gases, are purified from CO_2 and H_2S by being passed through a pipe into scrubbers contg. Na_2CO_3, the gas then passing by a pipe to Fe oxide purifiers for the absorption of any traces of H_2S remaining. The foul soln. is passed from the scrubbers by a pipe through a heater to a hot well and is raised by a pump to the top of a cooling tower in which the H_2S, CO_2 and CN compds. are driven out by a current of air or inert gas, and the revivified soln. from a basin is returned by a pump and pipe to the scrubbers. A portion of the soln. from the basin is passed by a pump to primary gas coolers, being thereby heated, and is returned by a pipe to the hot well to raise the temp. therein. A suitable construction is specified. (*C. A.*)

24. Heat insulation. E. T. HOLMBERG. U. S. 1,404,438, Jan. 24. A heat-insulating material adapted for use in metal cabinets is formed by moistening a mixt. of MgO 30 and infusorial siliceous earth 70% with a satd. soln. of $MgCl_2$ and compressing the mixt. in a mold. (*C. A.*)

25. Separating feldspar and quartz (hydraulic concentration). F. P. KNIGHT AND J. T. SHIMMIN. U. S. 1,404,974, Jan. 31. (*C. A.*)

26. Artificial meerschaum. P. DEUSSING. Brit. 172,004, Nov. 18, 1921. Addition to 164,319 (*Ceram. Abs.*, **5**, 59(1922)). The artificial meerschaum described in the principal patent, and consisting substantially of Hallic earth or roasted Meissner clay, raw Meissner clay, whiting, and quartz dust, is improved by the addition of kieselguhr to the ingredients or by substituting kieselguhr for the quartz dust. The compn. is molded, roasted, and finished in the manner described in the principal patent. (*C. A.*)

27. Filtering and oil-decolorizing earth. R. G. TELLIER. U. S. 1,402,112, Jan. 3. A filtering and oil-decolorizing material is prepd. by baking and oxidizing fuller's earth while agitated in an air current at a temp. of about 400–700°. (*C. A.*)

28. Heat-insulating material. H. S. ASHENHURST. U. S. 1,402,133, Jan. 3. An insulating material of light wt. is formed of $Al_2(SO_4)_3$, $MgCO_3$, gypsum and H_2O, with or without fiber, and a retarder. (*C. A.*)

29. Manufacture of carbon arc electrodes. W. MATHIESEN. G. P. 341,240, 31.7.20. Carbon prior to the burning process is subjected to pressure considerably higher than that employed in the moulding process. Such carbons used in the arc afford a higher crater temperature and greater light emission.

J. S. G. T. (*Jour. Chem. Ind.*)

Apparatus and Instruments

30. Electric carbon dioxide recording instrument. M. MOELLER. *Siemens Z.*, Dec., **1921**; *Elec. World*, **79**, 293(1922).—The temp. of an elec. heated resistance wire will depend upon the heat cond. of the gas surrounding this wire. The heat cond. of CO_2 is about 40% less than that of all the other gases contained in the flues of boilers. Consequently the temp. of the wire will be proportioned to the percentage of CO_2 contained in the flue gases. By using 2 wires, one operating in the flue gas and the other in air their temp. difference is detd. by their proportional ohmic difference. An instrument indicating directly CO_2% is used in parallel with a galvanometer. Fine Pt wires are used which change their resistance about 3.5% for each 10° temp. rise.

C. G. F. (*C. A.*)

31. A new comparison apparatus for colorimetric determination. O. MANNEBACH. *Chem.-Ztg.*, **46**, 20(1922).—The comparison tubes stand obliquely in a beaker of H_2O which is placed in a wooden box, black inside, open at the top, and with a round hole slightly smaller than the bottom of the beaker cut in the bottom. Under the box is a reflector which throws a suitable light up through the beaker, enabling a comparison of the most delicate tints. J. H. MOORE (*C. A.*)

32. A new radiation pyrometer. ANON. *Chem.-Ztg.*, **46**, 20–1(1922); 2 cuts.—The app. resembles a small telescope and may be used in the hand or on a tripod. The object or part of the furnace to be tested is brought sharply into the field of vision, the heat rays being at the same time automatically focused on the thermoelement which is seen in the field. The temp. is read on a scale just over the eye-piece. The app. may also be attached to a recorder, is accurate within 10–15° at 1000°, may be constructed with scales from 500–2000°, and, above 1 m., is independent of the distance of the object so long as the image of the latter in the field completely covers the thermoelement.

J. H. MOORE (*C. A.*)

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33. Apparatus for electrical precipitation of suspended particles from gases. L. BRADLEY. U. S. 1,400,795, Dec. 20. (*C. A.*)

34. Gas calorimeters. W. B. DAVISON. Brit. 171,246, Sept. 13, 1920. The products of combustion are brought into intimate association with a cooling liquid by passing both the products and the liquid through a common divided medium. (*C. A.*)

35. Viscosimeters. R. L. FRINK. Brit. 171,774, Aug. 20, 1920. The app. is particularly intended for measuring the viscosity of highly viscous materials, such as molten glass, and comprizes an angularly displaceable or rotatable member contacting with the material and means for measuring the speed of rotation of this member produced by a const. torque, or the torque required to produce a const. angular velocity. (*C. A.*)

36. Centrifugal separator. F. H. LINDENBERG. U. S. P. 1,395,193, 25.10.21. Appl., 8.3.17. A perforated conical basket with the wider end uppermost is adapted

to revolve about a vertical axis and is mounted for universal rotation about a centre in the axis. Spiral vanes within the basket are arranged to revolve differentially in the same direction as the basket to control the upward movement of material upon the surface of the basket. The basket and the vanes are revolved at speeds bearing a definite ratio by means acting in the transverse plane of the centre of rotation.

H. H. (*Jour. Chem. Ind.*)

37. Vacuum filtration apparatus. A. T. CARTNER, R. CLEWER, AND MATHER AND PLATT, LTD. E. P. 170,788, 21.1.21. A liquor trap is provided between the receiver and air pump of a vacuum filtration apparatus. The inlet pipe from the receiver extends nearly to the bottom of the trap and the outlet pipe to the pump terminates near the top and is provided with a valve seat adapted to be closed by a floating ball. Another valve operated by a float is adapted to admit air to break the vacuum in the event of the liquor rising too high. Perforated diaphragms are also provided within the trap on which may be placed an absorbent for any corrosive gases given off by the filtered liquor. B. M. V. (*Jour. Chem. Ind.*)

38. Filling material for use in Glover towers and similar apparatus. P. KESTNER. E. P. 170,982, 18.8.20. Addn. to 131,502 (J., 1919, 746A). The rings of ceramic material are made by stamping them in the form of truncated cones from a layer of ceramic paste by means of cutting punches. J. S. G. T. (*Jour. Chem. Ind.*)

Chemistry, Physics and Geology

39. Vapor pressure of some salts. II. H v. WARTENBERG AND H. SCHULZE. *Z. Elektrochem.*, **27**, 568–73(1921); cf. *C. A.*, **15**, 2376.—Measurements have been made of the vapor pressures of LiCl, CsCl, RbCl, LiBr, CsBr, RbBr, NaF, KF, LiF, CsF, RbF, NaI, CsI and RbI at a no. of temps. between the b. p. of the salt and 200–300° below the b. p. The vapor-pressure curves of the different fluorides are widely separated from one another; those of the other classes of salts lie closer together the higher the at. wt. of the halogen. H. JERMAIN CREIGHTON (*C. A.*)

40. Some conclusions in regard to the origin of gypsum. F. A. WILDER. *Bull. Geol. Soc. Am.*, **32**, 385–94(1921).—Gypsum deposits contg. less than 0.05% of $CaCO_3$ cannot have formed by the evapn. of sea water or of stream-fed inland basins. Circulating water which has dissolved disseminated gypsum is a primary factor in the formation of recent gypsum deposits. These deposits are further augmented by wind action and evapn. in inland lakes. The alteration of carbonate rocks or anhydrite may also explain some gypsum formations. W. F. HUNT (*C. A.*)

41. Recent advances in science—Mineralogy and crystallography. A. SCOTT. *Sci. Progress*, **16**, 374–77(1922).—Review of recent work in chem. crystallography.

J. S. H. (*C. A.*)

42. Metasomatism in siliceous rocks. V. M. GOLDSCHMIDT. *Geol. För. Förh.*, **43**, 463–8(1921).—An advance summary. W. SEGERBLOM (*C. A.*)

43. Notes on sodium silicate. A. ERDENBRECHER. *Mikrokosmos*, **15**, 55–60(1921). —The no. of mols. of H_2O which crystallize with Na_2SiO_3 depends on the compn. of the mother liquor. When 20–25 g. $Na_2SiO_3.9$–$10H_2O$ are dissolved in 40 cc. H_2O, the addn. of not more than 40 g. NaOH per 100 cc. of soln. yields $Na_2SiO_3.9H_2O$, rhombic, m. 47°; of 60 g. NaOH yields $Na_2SiO_3.6H_2O$, monoclinic, m. 63.5°; and of larger amts. of alkali yield $Na_2SiO_3.4H_2O$, hexagonal, m. 83–85°. Other hydrates of the metasilicate mentioned in the literature are probably mixts. of these as changes in the compn. of the mother liquor cause the crystals to change their degree of hydration. Excellent photographs of the various hydrates and their transformations are given.

W. S. (*C. A.*)

44. Electrical dust precipitation and gas purification (Cottrell process). L. PLASZ. *Metall. u. Erz.*, **18,** 539–47(1921).—The efficiency of com. pptg. app. varies from 86% on carbide furnaces to 99.99% on brown-coal combustion gases. The app. works without difficulty at 550°. About 50 plants are working in Germany and 200 elsewhere including about 100 in the U. S. Details of construction and operation are given.

R. S. D. (*C. A.*)

45. The determination of density and the methods of expressing it. F. BORDAS AND F. TOUPLAIN. *Bull. soc. encour.*, **133,** 1052–74(1921).—B. and T. discuss the various methods of expressing d. and the various methods of detg. it. They make a plea for a more definite statement of the method and conditions under which detns. are carried out, show the errors inherent in each method and the corrections to be applied in each case to get the abs. $d\frac{t^\circ}{4^\circ}$ *in vacuo* from the results obtained directly, and advise the use of the sp. gr. balance in preference to hydrometers, applying the necessary corrections, as otherwise the figures obtained are quite arbitrary. For purely scientific work the abs. d. *in vacuo* should be used to the exclusion of all others.

A. P.-C. (*C. A.*)

46. Diffusion in porous vessels. A. L. HERRERA. *Mem. rev. soc. cient. "Antonio Alzate,"* **39,** 343–47(1921).—When solns. of reactive salts are allowed to diffuse very slowly together, the ppts. or crystals formed show analogies to natural cells. A soln. of K silicate, d. 1.5 or more, contg. K_2CO_3 not in excess of *N*, is placed inside an unglazed porcelain cup, and the latter placed in $CaCl_2$ soln. of 1° Bé. After 24 hrs. numerous very fine tubes of Ca silicate are formed on the outside of the porous cup, which bear on their surface microscopic cells, and in some cases are formed entirely of the latter.

M. R. S. (*C. A.*)

47. Liesegang ring formation. H. A. MCGUIGAN. *Science*, **55,** 100–1(1922); cf. *C. A.*, **15,** 3011.—Polemic with Bradford, *C. A.*, **16,** 518. F. L. BROWNE (*C. A.*)

48. General colloid chemistry. IV. The physical-chemical analysis of aluminium oxy salts and aluminium oxide sols. MONA ADOLF AND WOLFGANG PAULI. *Kolloid-Z.* **29,** 281–87(1921).—Heating an excess of thoroughly washed $Al(OH)_3$ for a day with HCl gave a sol characterized by its inability to pass through parchment paper and by the fact that a small amt. of electrolyte coagulated it. The limiting value for the compn. of the sol was $[Al(OH)_3]_2.AlOCl$ and this value could be exceeded very little. By regulating the amt. of acid the pure oxy salts $Al(OH)Cl_2$ or AlOCl could be easily prepd. Neither a mixture nor an intermediate oxy salt between these two was obtained. By comparison with the mol. cond. of salts such as NaCl, $BaCl_2$ and $AlCl_3$, $Al(OH)Cl_2$ was shown to form three ions. The degree of ionization increased rapidly with diln. The steps by which ionization occurred, from the formation of $Al(OH)Cl^-$ to that of OH^- ions, could be followed by measuring the concn. of free Cl^- and of H^+ ions. The degree of hydrolysis was very small, being 0.25% as compared to 4.5% for $AlCl_3$ at a diln., $V = 1024$. The equiv. cond. for the Al constituent was normal for very dil. solns. but was surprisingly high, 99.7 mhos. at 0.068 *N*, at moderate dilns. This would be true if in addition to the normal ionization of $Al(OH)Cl_2$, complex ionization occurred so that free Cl^- ions would be used up, *e. g.*, $Al(OH)Cl_3|Al(OH)Cl$. Similar ionization has been shown for Zr compds. (cf. *Ceram. Abs.*, **5,** 104(1922)). Further proof of the fact was given by electroendosmosis expts. in a Landsteiner-Pauli app. At moderate dilns. both positive and negative Al constituents were present, while in very dil. solns. only the positive were present. Similar analysis of aluminyl monochloride, $Al(OH)_2Cl$ or AlOCl, proved it to be a two-ion compd. and that complex ionization, such as $Al(OH)_2Cl_2|AlO$, probably occurred. H. M. MCLAUGHLIN (*C. A.*)

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49. Alumina. D. TYLER. Brit. 172,087, Aug. 24, 1920. Al ores or Al-contg. materials such as clay, slags, or ashes are mixed with CaO or equiv. Ca or Mg compd. in such quantity that there are at least two mols. of CaO, etc., for every mol. of SiO_2 and in addition at least 1 mol. of CaO, etc., for every mol. of Al_2O_3. Allowance is made for any base that may be present. The materials are finely ground and then calcined; a flux such as fluorspar may be added. The product is treated with a soln. of an alkali salt such as Na_2CO_3 in order to give alkali aluminate and an insol. Ca or Mg salt. The former is then treated for the production of Al_2O_3. The $CaSiO_3$ which is left after the extn. is particularly suitable in *cement* manuf., since it is free from insol. alkali salts. Any potash present in the raw material is rendered sol. and is recovered from the alkali left after the pptn. of the Al_2O_3. Cf. 9662, **1915** (*C. A.*, **11**, 89). (*C. A.*)

50. Alumina and potassium compounds from feldspar or similar material. H. P. BASSETT. U. S. 1,404,083, Jan. 17. Feldspar or similar material is heated to redness with Na_2CO_3, Fe_2O_3, lime and Na_2SO_4 or NaCl for 1 hr. and the resulting reaction mixt. is treated with NaOH to form Na aluminate, which may be converted into pure $Al(OH)_3$. (*C. A.*)

51. Zinc oxide. METALLBANK UND METALLURGISCHE, AKT. GES. Brit. 170,082, July 9, 1920. $CaSO_4$-contg. Zn ppts. resulting from the treatment of Zn liquors contg. sulfate with CaO are freed substantially from their S content by heating and stirring the ppt. suspended in a soln. containing $ZnCl_2$ and Na or Ca chloride, and calcining the resulting basic $ZnSO_4$ after washing with H_2O to free it from $CaCl_2$, etc. The $ZnCl_2$ should be approx. equiv. to the sulfate present and may be added from external sources or may be prepd. *in situ* by means of the Na or Ca chloride. Alternatively, the process may be carried out during the pptn. of the $CaSO_4$-contg. $Zn(OH)_2$. Dil. milk of lime is slowly added to the Zn liquor heated, *e. g.*, to about 70°, to which has been added Na or Ca chloride. If the liquor has a high sulfate content it may be reduced prior to the above treatment by adding NaCl and crystg. out the resulting Glauber's salt. High concns. of Zn and of neutral salts such as Na and Ca chlorides facilitate the formation of the basic sulfate. (*C. A.*)

52. Electrolysis. C. E. HOLLAND. Brit. 171,670, Sept. 7, 1921. Finely divided coal and other org. matter, such as hydrocarbons suspended in H_2O, are coagulated and pptd. by electrolysis. A suitable app. is specified. (*C. A.*)

53. Concentrating ores. L. A. WOOD AND MINERALS SEPARATION, LTD. Brit 170,944, July 30, 1920. In a froth-flotation process, products obtained by treating viscous substances such as tars, fuel oil, or tar oil, with emulsifying agents such as caustic alkalies, carbonates, soaps, Na resinate, or mixts. thereof, are used as frothing agents or as a source of or in conjunction with frothing agents. *E. g.*, producer-gas tar may be heated with an aq. soln. of NaOH. Cf. 18,943, **1910** and 5454, **1915** (*C. A.* **10**, 2461) and *C. A.* **16**, 233. (*C. A.*)

Refractories and Furnaces

54. The illumination of the interior of kilns. ANON. *Taschen buch für Keramiker Keram. Rundschau*, **1922**, 41–42.—The illumination of the interior of pottery kilns during the setting and removing of the ware is a problem for manufacturers not equipped with elec. Kerosene lamps are dangerous since the kilns are emptied while still hot which may cause an explosion of the lamp. Rape-seed oil lamps have the advantage over kerosene in that they do not explode but these lamps give off an offensive odor when used in hot kilns which make them undesirable. Acetylene lamps have been found to be the best for this purpose since they do not explode or give off an offensive odor. H. G. SCHURECHT

55. Hot-blast stove rating. F. H. WILCOX. *Blast Furnace Steel Plant*, **10**, 29–32 (1922).—Stoves should be able to carry 1250° straight line heat, with a margin of heat reserve. It is good practice to burden the furnace to the max. degree on as high a blast temp. as it is possible to hold and maintain a heat reserve for emergencies. Coke consumption depends on the heating capacity of the stoves. The influence of five different checker sizes and of 3 and 4 stove combinations are shown for a 600-ton furnace. Brick of 1″ in depth functions efficiently in heat input and output. 400° is the practical limit for drop of temp. in stove brickwork. The load in a stove because of alternate heating and cooling is a "live load." Failures may come from springdown of tile arches and piers, shifting of checkers, expansion of ring walls and checkers or failure of dome. Operating troubles may be fluttering or surging, inefficient use of all of the checker area and insufficient draft due to small chimney valves, draft chambers and stacks. The most efficient dimensions of brick and checkers and the no. of stoves are discussed.

JAS. O. HANDY (*C. A.*)

56. An electrically heated forging and heat-treating furnace. G. M. LITTLE. *Trans. Am. Soc. Steel Treating*, **2**, 228–36(1921).—An account of the development of a resistance type elec. furnace for high temp. work. By surrounding a heating element of C plates, clamped together, with a blanket of hydrocarbon vapors, greater crowding is possible, thus permitting the production of a larger amount of heated metal. The heating element is suspended across the furnace chamber free from the walls or roof; the top lining to the furnace chamber is composed of bars of C covered with a thick layer of coke dust. The roof can not be melted and is protected from oxidation by the same blanket of hydrocarbon vapors which protects the heating element. Some data on the performance and cost of operation are given.

W. A. MUDGE (*C. A.*)

57. Refractories and their application to gas works and coke ovens. P. G. STRASSMANN. *Gas u. Wasserfach*, **64**, 777–81, 798–801, 811–18(1921).—The clay and quartzite resources of Germany, their properties, and manuf. into refractories are discussed.

J. L. WILEY (*C. A.*)

58. The electric furnace in melting and refining. J. B. C. KERSHAW. *Electrician*, **87**, 636–39(1921).—A review of the status of the elec. furnace in the English Fe and steel industry during 1921. The tendency in design has been to increase the power of the transformers rather than to follow the German and American tendency to increase the size of the furnace. The Héroult and the Electrometals are the furnaces most in favor.

LOUIS JORDAN (*C. A.*)

59. Expansion of some refractory materials at high temperatures. B. BOGITCH. *Compt. rend.*, **173**, 1358–60(1921).—Expansion curves for bricks of fused bauxite, clay, silica, chromite, and magnesia over the temperature range 0° to 1600°C are given. The smallest expansion is shown by the fused bauxite, which is suitable for the construction of furnaces subject to sudden changes in temperature. Silica bricks showed the most irregular expansion. They expanded rapidly up to 600°C and then only very slowly, and above 1000°C showed a slight contraction. The curve shows two break points at vacuum. It forms a crystalline, snow-white powder, readily soluble in water.

E. H. R. (*Jour. Chem. Ind.*)

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60. Calcining alunite. H. F. CHAPPELL. U. S. 1,401,136, Dec. 27. Alunite is calcined at a temp. sufficiently high to volatilize K_2SO_4 and convert all the Al compds. present into Al_2O_3. The mass is agglutinated at its surface by the partial fusion and softening of the K_2SO_4 and the agglutinated superficial layer is removed as it forms from the zone of high temp. in order to avoid volatilization of the K_2SO_4 which would otherwise occur. According to U. S. 1,401,137, Dec. 27, alunite is heated, after the greater

portion of the fumes of Sioxides have been given off, in the combustion zone of a rotary kiln in order to complete calcination. (*C. A.*)

61. Treating alunite. M. SHOELD. U. S. 1,401,741, Dec. 27. Alunite is heated to about 500–600° with 3–5% of C in a reducing atm. partially to decompose the Al sulfate without decompn. or volatilization of the K_2SO_4. The products are dissolved and crystd. (*C. A.*)

62. Brick furnaces or kilns. J. BOYER. E. P. 172,062, July 28, 1920. A single kiln, or each of a series of kilns, is provided with a partition, open at the top, whereby gases burnt on one side of the partition pass over it, through the material (bricks) to be fired on the opposite side of the partition and then pass out through flues in the floor of the kiln, the gases being supplied by a gas plant and drawn, with the air required for combustion, through the kilns by a suction fan. The chambers and flues may, if desired, be built of the materials to be heated or dried. When the kilns are arranged in series the hot gases may pass consecutively from one to another so as to heat each chamber in turn, suitable shutters being provided to control the flow of the gases, or the kilns may be arranged to form a tunnel, each chamber being then composed of two fixed side walls, with two movable walls built on the platform of a wagon which travels on a track through the kilns. The walls of the chambers may be made with parts of U-shape, the limbs of which engage with one another, so that one set of walls may be moved with respect to the other set and the size and shape of the chamber altered accordingly. Each kiln may also be provided with a heat-recuperating chamber, either movable or fixed, for heating the air required for the combustion of the gases. Such air may, if desired, be blown into the kiln under pressure. A. B. S. (*Jour. Chem. Ind.*)

63. Gas-fired continuous kilns. J. AND H. MORTON. E. P. 172,099, Aug. 28, 1920. In a gas-fired kiln having a number of chambers arranged in series, each chamber is in direct communication with the adjacent chamber through a number of apertures provided with dampers which are clamped between an angle-iron rail and a flat rail. These rails are supported on rollers in a transverse trough below the floor-level, the top of the trough being closed by bricks. The outer end of the rail projects into a recess in the outer wall of the kiln and is provided with a lever and screw mechanism by means of which the slabs can be caused to cover or uncover the openings to any desired extent. A. B. S. (*Jour. Chem. Ind.*)

Abrasive

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64. Abrasive. C. J. BROCKBANK. U. S. 1,402,714, Jan. 3. Bauxite is roasted with Na_2CO_3 or K_2CO_3 to combine with oxides present as impurities and the oxides are subsequently removed by fusion with C and treatment with H_2SO_4. (*C. A.*)

Stoneware, Whiteware and Porcelain

65. Porcelains for electric insulators. O. BOUDOUARD. *Chimie et industrie*, **6**, 583–91(1921).—See *Jour. Am. Ceram. Soc.*, **4**, 246(1921). A. P.-C. (*C. A.*)

66. Present demands on porcelain insulators. W. WEIKER. *Elektrotechn. Z.*, **41**, 1475(1921); **42**, 1508(1922).—A very comprehensive review. C. G. F. (*C. A.*)

Art and Design

See Abs. 7.

67. Relation between silica, alumina and basic oxides in porcelain glazes fired at high temperatures. YAICHIRO KITAMURA. *J. Chem. Ind.* (Japan), **24**, 89–105(1921).—227 different combinations were prepd. within limits of 1.0 RO, 0.2–2.2 Al_2O_3, 4.0–

26.0 SiO_2, using for RO, 0.5 KNaO + 0.5 CaO in one set, and 0.1 KNaO + 0.9 CaO for the balance. The Al_2O_3 was varied in 0.2 equiv. steps and the SiO_2 in 2.0 equiv. Burns were at cones 11, 14, and 17. The results are given in 6 charts. The limits for good glazes are much greater at the higher temp. Good glazes are (1) for 1.0 RO (0.5 KNaO, 0.5 CaO) at cone 11, 0.9 Al_2O_3, and 8.0 SiO_2; at cone 14, 1.05 Al_2O_3, 10.0 SiO_2; and at cone 17, 1.1 Al_2O_3, and 15.0 SiO_2. (2) For 1.0 RO (0.1 KNaO, 0.9 CaO), at cone 11, 0.7 Al_2O_3, 5.0 SiO_2; at cone 14, 0.95 Al_2O_3, 9.5 SiO_2; and at cone 17, 1.1 Al_2O_3 and 14.5 SiO_2. Suitable compn. of semi-mat and mat glazes are also discussed in detail. S. T. (*C. A.*)

Heavy Clay Products

68. The utilization of crude lignite for brick burning. WEIZZ AND BECKER. *Braunkohle*, **20**, 310–12(1921).—Whereas 180 kg. of hard coal are required to burn 1000 bricks, 500 kg. of dried lignite, such as Rhenish, are necessary. The utility and economy of lignite depend chiefly upon proximity to the source of supply. C. C. DAVIS (*C. A.*)

PATENTS

69. Pottery; artificial stone. R. TRALLS. Brit. 172,295, Nov. 25, 1921. Minerals contg. clay, lime, or iron and bituminous materials are smelted by means of their own combustible constituents in the production of castings. The minerals mentioned are various clays, lime formations, and iron oxides which are found in lignite and black coal swamps, turf or moor deposits, or independent deposits such as aluminite, oil schist and certain marls having bituminous constituents. The air dried materials are heated in a smelting furnace by the waste combustible gases until incandescent, when the combustible constituents complete the smelting. If necessary, a small proportion of coal, etc., may be added and a flux such as lime, gypsum, fluorspar, etc., introduced. For coloring and varying the quality of the casting, metals or metallic compds. are employed. (*C. A.*)

Glass

70. The effect of temperature upon the ultraviolet absorption of glasses. WALTER RIEDER. *Jahrb. Phil. Fak. II, Univ. Bern.*, **1**, 148–54(1921).—Twelve var. of glass were studied at temps. up to 450° and in one case down to the temp. of liquid air and with wave lengths down to 2250°. All var. exhibited a transmission limit below which the transmission for all shorter wave lengths was zero. Increase of temp. in all cases raised this transmission limit toward the region of longer wave lengths. The var. data are recorded in the author's thesis Ms. in 48 tables. The present paper is only an abs. E. W. W.

71. The interaction of silica, sodium oxide and barium oxide. Part XII of "The Development of Various Types of Glass." C. J. PEDDLE. *J. Soc. Glass Tech.*, **19**, 201–11(1921).—Two series of glasses were prepd. and studied. One series was based on mol. type 100 SiO_2, 40 Na_2O, x BaO, where x varied from 5 to 40 at intervals of 5, the other based on mol. type 100 SiO_2, 20 Na_2O, x BaO, where x varied from 5 to 40 at intervals of 5. The *density* and *refractive index* increase with an increase in barium oxide and also with an increase of sodium oxide, the increase for sodium oxide holding for d. when the mol. barium oxide content is less than 16 mols. and for refractive index when the content is less than 25 mols. Total *dispersion* increases with the addition of either barium or sodium oxide, the rate of increase being greatest in barium series containing the least sodium oxide. Most of the glasses tested did not have good weathering properties and were easily devitrified. W. C. TAYLOR

72. The interaction of silica, potassium oxide, and barium oxide. Part XIII of "The Development of Various Types of Glass." C. J. PEDDLE. *J. Soc. Glass Tech.*, **19**,

212–220(1921).—Two series of glasses similar to those in Part XII of this series except with K_2O instead of Na_2O, were prepd. and studied. It was found in these series that the *density, refractive index,* and total *dispersion* increase with increasing barium content and that the *solubility* decreases as the barium oxide content increases. All the glasses showed a tendency to *devitrification.* W. C. TAYLOR

73. The interaction of silica, barium oxide, and the oxides of sodium and potassium. Part XIV of "The Development of Various Types of Glass." C. J. PEDDLE. *J. Soc. Glass Tech.*, **19,** 220–28(1921).—Glasses of the mol. types 100 SiO_2, Na_2O, 20 K_2O and 100 SiO_2, 10 K_2O, 10 Na_2O, x BaO were investigated, x varying from 5 to 40 mols. As in the other series the *density, refractive index* and *total dispersion* increases as the proportion of barium oxide increases, the *solubility* increasing as the barium oxide content decreases. None of the glasses were of first class durability. W. C. TAYLOR

74. A comparison of the alkali-barium oxide-silica glasses. Part XV of "The Development of Various Types of Glass." C. J. PEDDLE. *J. Soc. Glass. Tech.*, **19,** 228–256(1921).—A long series of soda barium, potash barium and soda-potash barium silicates were studied. Statistics are given in regard to effect of compn. on *color, density, refractive index, dispersion, devitrification, form of crystals, solubility, durability,* and *pot attack,* and some general conclusions drawn. W. C. TAYLOR

75. A comparison of the alkali-barium silicate and alkali-lead silicate glasses. Part XVI of "The Development of Various Types of Glass." C. J. PEDDLE. *J. Soc. Glass Tech.*, **19,** 256–68(1921).—A comparison of the results obtained in the preceding papers on lead and barium glasses discussing the relative effects in regard to *density, refractive index, total dispersion, value, devitrification, solubility and durability.* W. C. TAYLOR

76. The shrinkage porosity and other properties of British fire-clay after being fired at high temperatures. EDITH M. FIRTH AND W. E. S. TURNER. *J. Soc. Glass Tech.*, **19,** 268–76(1921).—Detns. of the shrinkage, porosity, and apparent and real *specific gravities* of 26 British and 1 German clay were made at 1500°C. Ten of the clays including the German, undergo permanent linear expansion between 1400° and 1500°; seven including the German, undergo decrease of apparent sp. gr. and only two show appreciable increase of porosity; two of the clays underwent over-firing before 1500° and two developed blistering to a slight extent. (*Jour. Amer. Ceram. Soc.*, **4,** 68(1921)). W. C. TAYLOR

77. The density of glasses containing aluminum. S. ENGLISH AND W. E. S. TURNER. *J. Soc. Glass Tech.*, **19,** 277–80(1921).—Curves are given to show d. of *sodium-calcium, sodium-magnesium* and *sodium-aluminium silicates.* Although wt. for wt. 1% of magnesia, the substitution of alumina for lime or soda reduces the d. very considerably. Density factors are also discussed. W. C. TAYLOR

78. Measurement of the double refraction in tempered glass. TAFFIN. *Compt. rend.*, **173,** 1347–50(1921).—The double refraction in the strained glass is balanced by that caused in an annealed plate of glass under a variable load in a testing machine. E. D. WILLIAMSON (*C. A.*)

79. Polishing glass by means of acids. O. PARKERT. *Zentr. Baukeram.*, **35,** 1–2 (1920); *Chimie et industrie,* **6,** 631(1921).—The material to be polished is thoroughly cleansed by means of a 12% H_2SO_4 and 1% HCl bath. It is then immersed for 45 sec. in a bath consisting of 1 part water, 2 parts H_2SO_4, and 1 part HF, which is kept at 35°, and is then washed with water. If necessary the treatment is repeated. Fine glassware is sometimes rubbed with putty powder. A. P.-C. (*C. A.*)

80. Annealing of glass. E. D. WILLIAMSON. *J. Wash. Acad. Sci.*, **12,** 1–6(1921).—A mathematical discussion of the most rapid methods of annealing glass. Schedules are given for carrying out the process in a shorter time than has previously been used. E. D. WILLIAMSON (*C. A.*)

81. A novel leer installation. ANON. *Nat. Glass Budget*, **37**, No. 34, 14(1921).—The Columbia Glass Co. of Fairmont, W. Va., is trying out a small leer of steel and asbestos which requires no external heat for its operation. The newly made ware is introduced into it quickly and the excellent insulation of the leer conserves the original heat of the glass sufficiently to anneal it in $^3/_4$ of an hour. The chief difficulty, it is claimed, is the regulation of the heat to avoid melting the ware.

J. B. PATCH (*C. A.*)

82. Recommended specifications for limestone, quicklime, and hydrated lime for use in the manufacture of glass. ANON. The Bur. Standards, *Circ.*, No. **118**, 7 pp. (1921).—This is based on a draft originally prepared by A. E. Williams, of the Glass Section of the Bureau, and has been unanimously approved by a "conference" composed of representatives of the Geol. Survey, Bur. Mines, Bur. Soils, Bur. Chemistry, Forest Service, Fixed Nitrogen Research Lab., and The Chemical Warfare Service. It has also been "adopted as tentative by a majority vote of the Standardization Committee of the Glass Division of the Am. Ceramic Society." G. E. BARTON (*C. A.*)

PATENTS

83. Glass manufacture. T. B. KETSON. Brit. Pats. 170,882, 170,883, May 7, 1921. *Ill. Off. Jour. Pats.*, Dec. 21, 1921, p. 5707. Relates to bottle blowing machines, and ratchet gearing for same. With illus. WM. M. CLARK

84. Glass manufacture. PHILLIPS LAMP WORKS. Brit. Pat. Appl. 172,289. *Ill. Off. Jour.*, Jan. 25, 1922, p. 6223. Describes a process for drawing glass tubing or cane continuously from a supply of molten glass. The metal flows from a tank inside an inclined rotating cylindrical chamber, which is heated. Diagrams included.

WM. M. CLARK

85. Glass working. BRIT. THOMSON-HOUSTON CO. AND G. E. CO., Brit. Pat. 171,232, Sept. 3, 1920. *Ill. Off. Jour. Pats.*, Dec. 30, 1921, p. 5837. Describes a machine for flaring the ends of glass tubes, especially those used as parts in the manuf. of incandescent lamps. Sketched. WM. M. CLARK

86. Glass. E. W. ENEQUIST. U. S. 1,403,752, Jan. 17. Basic soda slag contg. ferrous Fe is used in glass together with sand and other glass-making materials to form a black glass adapted for use alone or as a glaze. (*C. A.*)

87. Glass manufacture. WESTINGHOUSE LAMP CO. Brit. 170,563, Sept. 15, 1921. Glass which will resist the action of the vapors of alkali metals in vapor elec. lamps is composed of a mixt. of oxides such as Na_2O 13, Al_2O_3 15, CaO 12, B_2O_3 60%. Such glass withstands temps. of 400-600° in Na vapor lamps. (*C. A.*)

88. Glass manufacture; electric insulation. P. SCHUDI-FREULER. Brit. 171,692, Nov. 15, 1921. Black glass, which is of use as an elec. insulating material, and which has a small thermal expansion, is made by melting a natural rock such as schist, consisting chiefly of quartz, lime, and Al_2O_3 and adding a further quantity of one or more of these substances until the melted product contains approx. 1 part of Al_2O_3, 1.65 parts CaO, and more than 3.56 parts of SiO_2, the amt. beyond 3.56 parts being calculated so that all other oxides present may be converted into silicates. The main ingredient of the finished product has the chemical formula $(SiO_2)_6.Al_2O_3.(CaO)_3$ and melts at about 1250°. (*C. A.*)

89. Electric glass-annealing furnace. O. A. COLBY. U. S. 1,401,674, Dec. 27. (*C. A.*)

Enamels

90. Enamels for tinware. ANON. *Taschenbuch für Keramiker, Keram. Rundschau*, 37–40(1922).—

TABLE I

GROUND COATS

	I Fritt	II Fritt	III Fritt	IV Fritt	V Fritt
Boric acid	0.0	0.0	0.0	0.0	240.0
Borax	371.0	32.0	44.0	374.0	115.0
Feldspar	333.0	28.0	31.0	335.0	96.0
Quartz	192.0	20.0	17.0	196.0	231.0
Calcined soda	45.0	6.0	3.0	56.0	0.0
Fluorspar	37.0	3.0	4.0	39.0	38.0
Whiting	0.0	9.0	0.0	0.0	0.0
Potassium nitrate	22.0	2.0	1.0	0.0	0.58
Manganese silicate	0.6	0.5	0.0	0.50	212.0
Cobalt oxide	0.3	0.2	0.1	0.25	0.0
Nickel oxide	0.0	0.0	0.1	0.0	0.0
Magnesia	0.0	0.0	0.0	0.0	10.0
	Mill mixt.	Mill mixt.		Mill mixt.	Mill mixt.
Fritt	94	92		94	90
Clay	6	8		6	10

TABLE II

WHITE ENAMEL

	I Fritt	II Fritt	III Fritt	IV Fritt	V Fritt	VI Fritt
Feldspar	386.0	0.0	220.0	235.0	353.0	32.0
Quartz	190.0	297.0	175.0	314.0	205.0	8.0
Borax	154.0	229.0	300.0	162.0	168.0	26.0
Calcined soda	0.0	117.0	135.0	93.0	0.0	9.0
Cryolite	117.0	0.0	0.0	157.0	120.0	5.0
Potassium nitrate	65.0	80.0	20.0	31.0	64.0	3.0
Whiting	65.0	0.0	0.0	0.0	70.0	0.0
Fluorspar	13.0	0.0	0.0	0.0	20.0	6.0
Magnesite	10.0	0.0	0.0	0.0	0.0	0.0
Magnesia	0.0	37.0	0.0	8.0	0.0	0.0
Tin Oxide	0.0	240.0	150.0	0.0	0.0	11.0
	Mill mixt.	Mill mixt.		Mill mixt.	Mill mixt.	Mill mixt.
Fritt	84.0	94.0		90	85	86
Tin Oxide	10.0	2.0		6	10	8
Quartz	0.0	4.0		0	0	0
Clay	6.0	0.0		4	5	6

Colored enamels are obtained by the addition of the foll. ingredients. *Violet:* Manganese silicate; *Green:* Copper oxide with or without iron oxide or chromium oxide. With the last oxides one obtains only a translucent green, since tin oxide produces a pink tinge. Cryolite also spoils the green color. *Brown:* Iron oxide or manganese silicate; *Gray:* Nickel oxide or iron scale; *Black:* Cobalt oxide and manganese silicate; *Red:* For a cheap red, iron sulphate is calcined with alumina until the body takes a good red color. This color is then added to the enamel in a predetermined amount. Cadmium selenide and copper oxide and gold produce good red colors; *Rose:* Manganese oxide; *Orange:* Red ochre. H. G. SCHURECHT

91. Operating costs of electric furnace for baking vitreous enamel. ANON. *Elec.*

World, **79**, 286(1922); 1 illus.—Production was increased and costs were reduced by substituting elec. for oil-fired enameling furnaces. Detailed figures are given.
C. G. F. (*C. A.*)

92. Electric enameling oven. E. KRAMER. *J. Elec. Western Ind.*, **48**, 114(1922); 1 illus.—Details of construction and operation of an automatic oven enameling 40 lbs. of metal per kw. hr. C. G. F. (*C. A.*)

Cement, Lime and Plaster

93. Contribution to the knowledge of the processes which occur during the formation of mortars. AUGUST ZELLWEGER. *Lab. Anorg. Chem. Bern. Jahrb. Phil. Fak., II, Univ. Bern.*, **1**, 102–106(1921).—*Sedimentation experiments.* The oxides CaO, MgO, and CaO were separately treated with an excess of water or of solutions of electrolytes and the velocity of slime deposition measured. The influence of the various ions was in general the same for the different oxides and seemed to be determined largely by the colloidal condition of the oxide. The phenomena of adsorption and swelling apparently were involved in the behavior shown.

MgO volume changes. The volume changes which accompany the slaking of MgO were studied dilatometrically. An initial expansion followed by a subsequent contraction was observed. The relative influences of various salts upon the expansion were the same as in the sedimentation expts. The final contraction was not affected by electrolytes.

The hardening of MgO slime. The influences of various electrolytes were in the same order as in the preceding experiments.

Conclusions. Colloidal swelling is the first step in the slaking process and colloidal processes are responsible for the various phenomena which accompany slaking.
E. W. W.

94. Accelerated test of portland cement. S. KANOH. *J. Chem. Ind.* (Japan), **24**, 675–99(1921).—Different methods now in use for accelerated tests are classified. The test for strength is as important as the test for constancy of vol. when the test is to ascertain the quality of the cement in a short period. Comparison of strength, expansion, and degree of hydration of 2 cements at 97–8°, and also at room temp. (8–13° and 11–18°) showed that hydration and hardening are remarkably accelerated by rise of temp. The results obtained by other investigators from strength test may be due to the irregularities to their tensile tests, in which the strength retrogression in course of hardening in longer period may not be the indicator of the true characteristic of the cement, but may be the result of eccentric loading, to which the tensile briquets are subjected. The accelerated tests for strength should be made not for tensile, but for compressive strength of mortar of cement and sand. Twelve charts and 7 tables are given to show the detailed results. S. T. (*C. A.*)

95. A new hydraulic magnesium cement. A. CH. VOURNAZOS. *Compt. rend.*, **172**, 1578–80(1921).—Hydraulic cement can be made from Greek magnesite if it is burned at a temp. only just high enough to expel the CO_2 and then mixed with amorphous silica or some substance contg. it, *e. g.*, pumice, pozzuolana or volcanic ash. The ratio should be 2 MgO : SiO_2 (amorphous). Pumice from Santorin contains 65% of SiO_2, of which 18/65 is amorphous (sol. in dil. KOH). The pumice has also 15% Al_2O_3 and 3% CaO. The rest is Fe_2O_3, TiO_2, MnO_2, MgO and alkalies. Greek (Euboean) magnesite is calcined without vitrifying. The rise of temp. is checked at the CO_2 expulsion point and the heating continued at that level. The product is ground to 80-mesh and stored. When mixed with fine pumice or pozzuolana and water, setting takes place in 48 hrs. in air or 90 in water: hardening continues for more than a year. 100 parts of pumice, contg. 18% amorphous SiO_2, require 24 parts of pure MgO or 30 parts of calcined Greek magnesite. The pumice is ground to pass 60-mesh. 35 parts of sand

are added if contraction strains are to be avoided. This mixt., after gaging with water and hammering into molds, shows strength as follows in kg. per sq. cm. (× 14.48 = lbs. per sq. in.).

	Air		Water	
	Tensile	Crushing	Tensile	Crushing
7 days	6.50	81	5.40	65
28 days	9.25	105	7.00	72
3 months	14.50	144	10.75	98
6 months	18.50	181	14.20	118
12 months	21.20	201	17.75	141

Max. strength is not then reached. Mortars are unchanged in appearance. Color is gray and grain is fine. They take paint well and may be used for interior or for exterior walls. They attack iron less than portland cement mortar does and their coeff. of expansion is almost that of iron. This magnesian cement is well suited for use in reinforced concrete. A pure white imitation marble, etc., may be made from 100 parts calcined magnesite, 60 parts amorphous SiO_2 and 70 parts of 30-mesh quartz sand. It sets in 40 hrs. It is unalterable like the pumice cement but no stronger. It is called "Leucociment." J. O. HANDY (*C. A.*)

96. Acid-proof cements and stone. THEO. UTZEL. *Chem.-Ztg.*, **45,** 1069–70(1921).—Cements based on water-glass are used extensively in the chem. industry. In H_2SO_4 plants they are used for luting the joints of monte-jus and for setting tiles in the denitrating towers. Because such cements harden quickly at the surface but only very slowly inside, they are often forced out by pressure before complete setting. Setting can be hastened by application of dil. HCl or H_2SO_4 to the cement in the joint. Even then, the inner part of the cement may not be affected. If more porous tiles are used the cement hardens better. German patent 784,111 relates to a process for making acid-proof stone. JAS. O. HANDY (*C. A.*)

97. The protection of concrete and cement against the action of sulfates by means of barium carbonate. H. NITZCHE. *Cement*, **10,** 1–2, 13–5(1921); *Chimie et industrie* **6,** 799(1921).—N. considers that after all the $BaCO_3$ has reacted with the sulfates, the action of further quantities of sulfates takes place quite readily. The reaction $BaCO_3 + CaSO_4 = BaSO_4 + CaCO_3$ is probably not the only one, and other reactions and accessory phys. phenomena probably come into play. Mortars to which no $BaCO_3$ had been added behaved very well, both when immersed in sulfate-bearing waters and when exposed to the atm. for 4 weeks, while all the samples treated with $BaCO_3$ behaved abnormally to varying degrees. A. P.-C. (*C. A.*)

98. The chemical composition of cement. D. I. BUJOR. *Contrib. Stub. Compoz. Chim. Ciment*, **1920,** 5–18; *Chimie et industrie*, **6,** 799(1921).—During the calcination of a mixt. of clay and limestone at 1200–1700° the partial fusion of SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO gives rise to a semi-fluid soln. which reaches a state of mol. equil. SiO_2, Al_2O_3 and Fe_2O_3 are equiv. and constitute the acid portion, while CaO and MgO are equiv. and constitute the basic portion. Within the limits of the chem. equil. the proportions of acid constituents can vary rather widely, while the basic constituents vary within very narrow limits. The equil. in the semi-fluid soln. is represented by $(SiO_2 + Al_2O_3 + Fe_2O_3) : 2.34\ (CaO + MgO)$. On cooling it solidifies completely forming pure cement. Below 1200° the proportion of pure cement is lower, part of the $CaCO_3$ being undecomposed or remaining as free CaO and part of the clay being mixed with the cement as insol. silicates. Above 1700° CaO and the excess of SiO_2 form silicates low in CaO which do not set with water. A. P.-C. (*C. A.*)

99. Researches with blast-furnace slags. H. BURCHARTZ. *Mitt. Materialprüfungsamt*, **38,** 149–63(1921); cf. *Ceram. Abs.*, **5,** 50(1922).—This is the 3d and final report to the Commission for the Investigation of the Suitability of Blast-furnace Slag for Con-

crete. Previous tests at Heligoland had not shown durability in sea water but the mixt. had been lean. The new tests lasted 3 years and were carried on with concrete made in one case with portland cement and in the other with iron portland. The slag sand and coarser sizes were carefully graded to obtain max. d. Check samples were made up with no slag but with Rhine sand and gravel. Slags from several sources were tried. Steel reënforcement, clean, rusty or scale covered were embedded. All of these metal samples were free from rust in a short time and none became rusty later, the samples having been perfectly protected from both air and sea water for 3 years. This was true also of the sand and gravel concrete. The d. of concrete controls its durability in sea water. The mixts. were 1 part cement, 2 parts slag-sand and 3 parts coarser slag. The slag-sand varied from 1 to 7 mm., the coarser slag from 7 to 25 mm. and from 25–40 mm., the latter forming $^2/_3$ of the coarser slag. After 3 yrs. the concrete made with iron portland cement was 9% stronger than the portland in the case of the slag mixt. and 6% in the sand and gravel one. Slag concrete from portland cement was 5% and from iron portland it was 8% stronger than sand and gravel concrete. JAS. O. HANDY (*C. A.*)

100. Relation between the clay content and certain physical properties of soil. B. A. KEEN AND H. RACZKOWSKI. *J. Agric. Sci.*, **11**, 441–49(1921).—A simple process for determining the following physical properties of soils is described: Apparent specific gravity, water taken up by unit volume of soil, pore space, specific gravity, volume expansion of soil when saturated with water. The specific gravity and apparent specific gravity vary inversely, and the absorptive power for water, the pore space, and the volume expansion of the saturated soil vary directly with the percentage of clay in the soil. The effect of organic matter on the constants mentioned is approximately the same, weight for weight, as that of clay. A. G. P. (*Jour. Chem. Ind.*)

101. Flocculation of soils. II. N. M. COMBER. *J. Agric. Sci.*, **11**, 450–471(1921). (Cf. J., 1920, 793 A).—The clay particle is assumed to consist of a central core surrounded by an emulsoid protective layer, and coagulation may result in three ways. "Normal" flocculation, as by salts of iron and aluminium, is precisely similar to the coagulation of electro-negative suspensoids by electrolytes. "Indirect" flocculation results from interaction between the flocculant and the constituents of the clay particle, whereby normal flocculants are produced. The action of some neutral salts and acids is of this type. "Abnormal" flocculation, as in the case of lime, is due to a reaction between the flocculant and the emulsoid surface layer of the particle. Although the flocculating effects of calcium hydroxide are reversible to carbon dioxide, the formation of calcium carbonate is not an essential part of the process. The hydroxyl ion may function in two ways in conjunction with the calcium ion. If added with or after the calcium ion, it produces the necessary alkalinity for the reaction between calcium salts and silica, etc. but if added before the calcium, the emulsoid surface of the clay is peptised and flocculation becomes more rapid and the volume of the coagulum greater. The difference in the action of lime on clay and on silt particles depends only on the relative proportions of emulsoid surface and core of the particle. A. G. P. (*Jour. Chem. Ind.*)

PATENTS

102. Cement composition. H. RICH. U. S. 1,404,060, Jan. 17. A mixt. adapted for road surfacing or brick making is formed of finely ground portland cement and clay together about 32, earthy material about 64 and finely powdered glass, SiO_2 or other similar hard material about 1–5 parts. KNO_3, S and creosote may be added. (*C. A.*)

103. Potash and white cement. A. C. AUGEN. Can. 213,611, Oct. 4, 1921. Mineral-contg. silicates of Fe and K are roasted with lime and salt, the coarser parts are sieved out and reground and the whole is treated under pressure in a closed vessel with steam and hot water to wash out the K. The water is sepd. from the solid matter, which is mixed with lime and roasted to produce white cement. (*C. A.*)

104. Kiln for burning lime or cement. J. H. LEMMON. U. S. 1,401,481, Dec. 27. The kiln has a central bridge wall spaced to allow for expansion and provided with gas supply flues. (*C. A.*)

105. Cold glaze for cement. K. FRIEDRICH. U. S. 1,402,412, Jan. 3. A cold glaze for cement or other building materials is prepd. by mixing a finely sifted sand-free colored cement with an aq. emulsion of derivs. obtained by oxidizing bituminous material in the presence of alkalies and free from volatile oils. (*C. A.*)

106. Cements. BOMBRINI PARODI-DELFINO. Brit. 170,063, July 5, 1920. A slow-setting cement free from Ca aluminates and ferrites is prepd. by adding Fe_2O_3 to the usual ingredients of portland cement, so that the ratio of Fe_2O_3 to Al_2O_3 is between 1 and 1.563 to 1. Siliceous sand is also added to restore the ratio of SiO_2 to sesquioxides to the normal value. The materials are treated in the usual manner. (*C. A.*)

107. Manufacture of earthenware. C. E. FULTON. U. S. 1,398,014, 22.11.21. Appl., June 7, 1919. Material for the manufacture of clay goods is treated with a mixture of an alkali hydroxide, a soluble alkali silicate, and a deflocculating agent of the nature of gallic acid. C. A. K. (*Jour. Chem. Ind.*)

BOOK REVIEWS

Fluidity and Plasticity. EUGENE C. BINGHAM, PH.D. International Chemical Series. pp. x + 440 + 96 figures. McGraw-Hill Book Company, New York, 1922.

Bingham after many years of careful and painstaking experimentation in the field of plastics has finally brought out a work that will prove to be a standard of reference in a nearly virgin field.

The author develops and clarifies the laws of flow in a way to suit the mathematically as well as the experimentally inclined. He neither sidesteps mathematical derivation of formulae where necessary, nor does he fail to give consideration to the more technical aspects of flow.

The laws of flow as related to gases, liquids, solutions, suspensions and solids are up in order in the first few chapters and applications of the same to technical processes are made in the latter half of the book.

The arrangement of the text is excellent. A summary of the fundamental considerations in a few of the chapters is given. It is so thorough that one feels that this could have well been continued throughout the text.

Not of least value are the appendix and index, which latter takes the form of a very complete bibliography. The appendix contains sections of practical viscometry and plastometry, technical viscometers and some valuable tables.

The book is vital to ceramic research and technology. It is hardly fair to commend one chapter above another but those of more vital interest to the ceramic man are "Viscosity and Fluidity," "Colloidal Solutions," "Plasticity of Solids," "Lubrication" together with the appendix above mentioned.

After a careful examination of the book one can not but feel that a wide gap in our literature has been adequately filled. G. A. BOLE

Zirconium and Its Compounds. FRANCIS P. VENABLE. American Chemical Monograph Series. Pp. 169. The Chemical Catalog Company, Inc., New York, 1922.

A thorough compendium of this subject. The book takes up the history, the reduction and properties of the metal, and the compounds of the various classes in an orderly way. It closes with analytical methods and technical applications. Then follows a complete list of patents with abstracts of each and a complete bibliography. In this the author's twenty original contributions deservedly shine. The text is replete with references. The presswork and binding are excellent. F. G. JACKSON

BULLETIN

of the

American Ceramic Society

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical and Scientific Questions and Promotion of Co-operative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

F. H. RHEAD, M. C. FARREN — Art
B. T. SWEELY, R. R. DANIELSON — Enamel
J. C. HOSTETTER, A. E. WILLIAMS — Glass
J. S. McDOWELL, F. A. HARVEY — Refractories
F. K. PENCE, C. C. TREISCHEL — White Wares
A. F. HOTTINGER, R. L. CLARE — Terra Cotta
C. F. TEFFT, M. B. GREENOUGH — Heavy Clay Products

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Vol. 1 **June, 1922** **No. 2**

EDITORIALS

THE BULLETIN, A FORUM OF MUTUAL HELP

Workers and foremen at the leer, the press, the kiln, in the dryroom, or the decorating shop know a great deal. They can express it in the language of the shop and this is the language that directs the making of the output. They must be encouraged to talk, made to feel that what they know is important, given aid if needs be in writing out their observations. They must learn that "Ceramics" is not high-brow stuff, however much we have to concentrate on the chemistry and physics of it. Nobody ever made ware from mixtures of feldspar, kaolin, fluorspar, etc., that are expressible in exact chemical formulae. The empirical formulae which we use are abstractions and we know it. They are chemical and physical modifications; a means of codifying results; a systematic means of analyzing the empirical observations made in the shop. But we can not analyze intelligently, if we do not have record of observations from the many shops.

The *Journal* is recording observations from many laboratories, but substantial progress can be made much more rapidly and with much less expenditure of time and material if the factory operators will in like manner make record of their observations. The operator is naturally abashed by the ability of expression of the theoretically trained man. Some operators are confused by the idiom in which these trained men write. Too often they try to hide it by pretending to understand, and then creep into

their shells. And often they have a chance to see, in the pitiless logic of results, that college training has not always made for either judgment or straight reasoning.

If all are to profit most, the hand of equal fellowship must be extended. The *Bulletin* is the medium for doing this. It is to be hoped that many of our technical men will present in these columns concrete applications of the results of research to concrete problems of plant operation. The operators must profit by these, hence the language must be their language, which does not mean, of course, a perversion of English, but freedom from the abstractions and condensations they do not use or understand. The spirit should not be that of instruction, but the giving of information to draw out information in return.

Should not this platform of information and interchange of practical and scientific observation be of mutual advantage?

KARL LANGENBECK

THE AMERICAN CERAMIC SOCIETY AND THE POTTERY INDUSTRY

More than ever there is need at the present time of a clearing house for the collection and distribution of technical information pertaining to the pottery industries. Without underestimating in the slightest degree the ability the American manufacturers have shown in advancing and extending their business it is a fact that at no time has it been so essential that the knowledge of raw materials and the study of processes be brought to a new level of accuracy and reliability. It is only in this way that competition, both foreign and domestic, can be met adequately.

It is necessary in the first place that we learn to differentiate the various raw materials now on the market and new ones as they may appear, and to purchase them on the basis of specifications which are fair and equitable and which have a legal status. Such specifications would be a protection both for the buyer and seller and would eliminate the uncertainty which often exists as to the qualities really desired. Again, there are many questions relating to factory operations and the fundamental principles involved upon which further light is necessary, in order that the burden of responsibility and uncertainty under which the master potters labor may be lightened. We need only cite a few of the difficulties which constantly appear such as crazing, dunting, blistering and splitting out. We need more information concerning the best sagger mixtures and their most thorough preparation. Again, we certainly must work toward a solution of the firing problem. What improvements can be made in existing kilns and what type of kiln is to be adopted in the future? In brief, there is distinct need of solving these general problems by co-operative effort.

In doing so collectively we need not interfere with individual effort or encroach upon the work of plants who conduct investigative work of their own, since some of the questions confronting us are too large to be solved by any single firm, no matter how strong its position may be.

It is in this work that the Amerian Ceramic Society may be of great value. The Society therefore invites the co-operation of the manufacturing potters. It is the one agency best equipped to do such work and to render service of a kind which will help place our pottery industries in the lead. It is to be hoped that all who are engaged in the pottery industry or connected with it will identify themselves with the Society and take an active part in the work of the division dealing with wh ite wares

ALBERT V. BLEININGER

THE ART DIVISION

Its Activities and Its Possibilities

This is one of the seven Divisions of the American Ceramic Society for the promotion of Ceramic Arts and Science. The Division recognizes that Ceramic Technology and Science must go hand in hand with craftmanship if there is to be the fullest development of the Ceramic Art profession.

The artist who attains the largest success has a working knowledge of the materials with which ceramic wares are fashioned and decorated. Modeling, sculpture, design and coloring; the use of pastes, glazes and stains to produce commercial ware that is distinctive and pleasing to the eye; these are the tasks of the artist. The production of ceramic bodies, glazes, pastes and stains suitable for ware that shall be both serviceable and artistic is the task of the ceramist. It is self-evident that a working knowledge of the media with which the artist works and of the methods employed in fabrication of ceramic wares is necessary before an artist can create ceramic art pieces.

The "Lost Art in Potting" is a divorcement of the creative ability of the artist and the knowledge of the ceramist. To him who has available both the knowledge to compound and the ability to fashion and decorate, there is no such thing as the "Lost Art in Potting."

It is significant that the highest quality wares are made in those countries where the young potter not only serves apprenticeship in a pottery but also has opportunity to attend art schools in which he learns the art of fashioning and the science of compounding.

The Art Division of the American Ceramic Society was organized in recognition of the industrial need for co-ordinating Ceramic Art and Ceramic Science. This Division will succeed in this only to the extent to which the artists co-operate. This is an opportunity for the artists to join with

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the ceramic technologist in making possible a distinctive American Ceramic art in American studios, clubs, schools and industry.

Program of Activities

1. Activities in the Interest of the Novice Ceramic Artist.—American artists of School and Club are interested chiefly in faience and majolica tile and pottery. To them the decorative possibilities of the different types of enamels, mat, crystalline and colored glazes, and the possibilities of each type at different heat treatments are for the most part unknown. Knowledge of under-glaze pastes, their composition, preparation, and use is not generally possessed by these novitiate artists.

The Art Division of the American Ceramic Society will give the opportunity for those who join in support of the Society by membership subscriptions to collaborate with the ceramic technologists in furnishing information regarding:

(*a*) Clays, body mixtures, methods, glazes, colors, firing, etc.
(*b*) Courses of instruction.
(*c*) Equipment.
(*d*) Sketches of shapes and designs.

2. Activities in the Interest of the Industrial Artist.—The many methods employed in decorating ceramic ware will be described and illustrated and advice given on suitability of each to particular types.

3. Activities in the Interest of Ceramic Art and Technical Schools.—The stress that is given abroad to the importance of private and Government schools for the teaching of Ceramic Art and Science is evidence that worth-while returns have been enjoyed.

The promotion of industrial schools, in collaboration with the White Wares Division, for the teaching of ceramic technology and ceramic technique will be one of the activities of the Art Division.

The Value of Membership in the American Ceramic Society to Ceramic Artists

1. This is the only national organization that gives opportunity for the ceramic artist to collaborate with the ceramic technologist.

2. Opportunity will be given to obtain information on ceramic mixtures for all sorts of decorative purposes.

3. Opportunity for discussion and exchange of experience will be found in the *Bulletin*.

4. Information regarding equipment and supplies for studios will be given when requested.

5. Description of methods of preparing the materials for and the shaping of wares will be made, including drawings, etc.

6. The Art Division will in fact be a "collective bargaining" for the advisory services of the best ceramic technicians and artists.

7. Compilation of "up to the minute" information on all sorts of items of value to ceramic artists will be published and sold to members of the Society at a large reduction. At the present time members receive a forty per cent reduction on all publications of the Society.

8. The extent to which the program of activities here outlined can be carried through is in direct proportion to the support given by the ceramic artists. Can any ceramic artist afford to refuse his share in making this possible?

9. The Society has served the ceramic interests well and with increasing success for twenty-four years. It is not a new or novel enterprise and has thoroughly proved its capacity and ability.

OUR BUDGET FOR 1922

On page 124 of the Abstract Section of the April issue of the *Journal* is the budget for the calendar year 1922. Summarized, the figures are as follows:

Income		Expense	
Membership Subscriptions	$19,000.00	Publications	$18,575.00
Advertising	17,700.00	Commission	4,185.00
Other Incomes	3,180.00	Executive	12,620.00
	$39,880.00	Divisions and Committees	4,500.00
			$39,880.00

These figures set the goal to be attained this year in facilities for service. If the Society is to give the service which the Board of Trustees decided should be the minimum during 1922 it will be necessary to realize a net increase of 300 Associate Members at $7.50 and 150 Corporation Members at $25.00 per annum; and it will be necessary to sell about $2000 more advertising.

Object of the Society.—Certainly the prime objective of the Society is not the publication of a journal. If issuance of a journal were the chief objective, the Society is proceeding in a very unbusinesslike fashion. The *Journal* is essential to the fundamental purposes of the Society but it is in no wise a commercial proposition.

The *Journal* is a record of researches made, and a medium for promoting organized research. It is the most important of the working tools of the Society.

The service rendered by the contributors, the abstractors, and the associate editors is of inestimable value. The "goods delivered" by the Society are in the *Journal*. It is a record of the things accomplished not only by our own members but by all investigators the world over. The

Journal, however, never has been and never will be the motivating and activating reason for ceramic craftsmen, executives and technologists giving support to the Society. More subscribers to the work of the Society are desired that the Society may the more efficiently and effectively promote the Ceramic Arts and Sciences by laboratory investigations and plant application and not simply to support the publication of a journal. The requirements of these industrial times are more exact information of all sorts, a more thorough knowledge of how to effect economies and of how to meet the market specifications as to quality. The obtaining and the applying of such knowledge is the prime purpose of the Society. Such service when rendered will bring cash profit to the employee for thereby his value to his employer is increased. Such service will bring cash profit to the corporations that make plant application of the things thus discovered and proved.

The budget figures show what is needed by the Society if it is to meet its obligations in the big scheme of co-operative research demanded by present industrial conditions, and if it is to be of the value to its subscribing members which they have a right to expect.

The Society needs more effective working tools if it is to serve the ceramic crafts in the fashion and to the extent demanded of it. The production of the sort of information and the publication of it in the sort of journal which these times require costs real money.

This is the why and the wherefore of the goal of 300 more personal members at $7.50, 150 more corporation members at $25.00 per annum, and increased advertising.

ACTIVITIES OF THE SOCIETY

Facts about the Summer Excursion to England and Europe

Date of sailing	August 22, 1922
Steamer	Aquitania, Cunard Line
Cost of passage, one person one way	$280.00
Latest date for taking up reservations	June 29, 1922
Person to be notified	Dr. E. W. Tillotson, Mellon Institute, Pittsburgh, Pa.
Duration of visit in England	About three weeks
Special arrangements made for visits to plants	Glass, White Wares, Refractories

Trips to the continent to be arranged individually with the assistance of Dr. Turner and Dr. Endell.

A special and urgent invitation has just been received from Vereinigte Grossaimerode Thonwerke, Grossalmerode, Germany, for us to visit them under the guidance of Dr. Endell.

The actual railroad travel will amount to about $40 and the hotel expenses will depend upon the class of hotels selected. One can certainly plan on $1000 to $1200 as a minimum for the entire trip.

Summer Meeting August 14–19, Inclusive

TORONTO, HAMILTON, MONTREAL, KINGSTON AND QUEBEC

The committee arranging for the summer meeting consists of

Millard F. Gibson, *Chairman,* The Interlocking Tile Co., Toronto.
N. B. Davis, O'Brien and Fowler, Ottawa.
L. H. Cole, Department of Mines, Ottawa.
Howells Frechette, Department of Mines, Ottawa.
G. Percy Cole, Dominion Glass Co., Montreal.
H. F. Dingledine, National Fire Proofing Co., Hamilton.
R. F. Segsworth, Feldspars Ltd., Toronto.
Everett Townsend, Frontenac Floor & Wall Tile Co., Kingston.
Randal K. Robertson, Cooksville Shale Brick Co., Cooksville, Ont.

The itinerary of ceramic plants and mines to be visited has not been worked out. Sufficient is it to tell at this time that no more pleasant week's jaunt could be planned. It will give opportunity to renew friendships and to spend restful hours on lake steamers. Modern plants of all sorts as well as feldspar mines will be visited. The route will probably take us down the Niagara Gorge from Niagara Falls to Lewistown, across Lake Ontario to Toronto, along the full length of the Lake, through the Thousand Islands, shooting the rapids in the St. Lawrence River and landing at that historic city, Montreal.

Details of cost and schedule will be announced as early as possible but this much is certain: no one can plan a more delightful summer excursion than that which the committee is arranging for the week of August 14.

Annual Convention of the Society

February 12 to 17, inclusive, Pittsburgh, Pa., is the time and place of the 1923 Annual Convention of the American Ceramic Society.

This will be the 25th anniversary, the Silver Jubilee celebration. It was in Pittsburgh that Elmer Gorton and Sam Geijsbeek made the proposal to Professor Orton that a Ceramic Society be organized, and it was in Pittsburgh that Professor Orton called together the first group of ceramists at that time and laid plans which developed into the incorporation of the American Ceramic Society.

The charter members are planning to make the first day of this convention a big occasion in the interest of Ceramic Science and Technology. The men who are doing big things for Ceramics will be with us on that day.

Calendar of Conventions

Electrical Manufacturers Club—Hot Springs, Va., second week of May, 1922, Fred L. Bishop, Sec., Hartford Faience Co., Hartford, Conn.

National Association of Purchasing Agents—Rochester, N. Y., May 15–20, 1922, H. R. Heydon, Sec., 19 Park Place, New York City

National Coal Association—May 17, 1922, W. B. Reed, Sec., 200 Commercial Bank Bldg., Washington, D. C.

American Society of Refrigerating Engineers—Detroit, Mich., May 24–26, 1922, W. H. Ross, Sec., 154 Nassau St., New York City

American Boiler Manufacturers Association—Stockbridge, Mass., May 29–31, 1922, H. N. Covell, Sec., 191 Dyckman St., Brooklyn, N. Y.

Ceramic Society (England)—trip to Sweden and Denmark, May 27–June 10, 1922, J. W. Mellor, Sec., Stoke-on-Trent, England

Tile Manufacturers Credit Association—June, 1922, F. W. Walker, Sec., 1 Reeves Bldg., Beaver Falls, Pa.

American Association of Engineers—Salt Lake City, Utah, June 4–6, 1922.

Electric Power Club—Hot Springs, Va., June 5–7, 1922, S. N. Clarkson, Exec. Sec., 1017 Olive St., St. Louis, Mo.

American Foundrymen's Association—Rochester, N. Y., June 5–9, 1922, C. E. Hoyt, Sec., Marquette Bldg., Chicago, Ill.

American Institute of Chemical Engineers—Niagara Falls, Ont., June 19–22, 1922, J. C. Olsen, Sec., Polytechnic Institute, Brooklyn, N. Y.

American Construction Council—Washington D. C., June 19–20, 1922; Organization Meeting

American Association for the Advancement of Science—Salt Lake City, Utah, June 22–24, 1922

American Society for Testing Materials—Atlantic City, N. J., June 26–July 1, 1922, C. L. Warwick, Sec., 1315 Spruce St., Philadelphia, Pa.

International Union of Pure and Applied Chemistry—Lyons, France, June 27–30, 1922.

National Bottle Manufacturers Association—July, 1922, C. R. Stevenson, Bus. Mgr., 120 Broadway, New York City

Annual Safety Congress of the National Safety Council—Detroit, Mich., August 28–September 1, 1922

American Chemical Society—Pittsburgh, Pa., Sept. 5–9, 1922, Charles L. Parsons, Sec., Washington, D. C.

Association of Iron and Steel Electrical Engineers—Cleveland, Ohio, September 11–15, 1922, John F. Kelly, Sec., Empire Bldg., Pittsburgh, Pa.

Eighth National Exposition of Chemical Industries—New York City, September 11–16, 1922

American Electrochemical Society—Montreal, Canada, September 21–23, 1922

National Association of Commercial Organization Secretaries—Chicago, Ill., October 23–25, 1922, John E. Northway, Sec., Hamilton, Ohio

National Exposition of Power and Mechanical Engineering—New York City, December 7–13, 1922

American Malleable Castings Association—January 10, 1923, Robt. E. Bolt, Sec., 1900 Euclid Bldg., Cleveland, Ohio

National Jewelers Board of Trade—New York City, Jan. 18, 1923, F. C. Backus, Sec., 15 Maiden Lane, New York City

American Concrete Institute—February, 1923, Harvey Whipple, Sec., East Grand Boulevard at Moran, Detroit, Mich.

Optical Manufacturers Association—Monthly meetings, Ernest H. Gaunt, 511 Westminster St., Providence, R. I.

Gypsum Industries Association—H. H. McDonald, Sec., 111 Monroe St., Chicago, Ill.

National Lime Association, June 14–16, Hotel Statler, Cleveland, Ohio

The Third Conference of the International Union of Pure and Applied Chemistry, June, 1922

The details concerning the importance of this conference are set forth editorially in the March issue of this *Journal*. Dr. E. W. Washburn with Dr. E. Ward Tillotson as alternate has been placed in nomination to the Division of Chemistry and Chemical Technology of the National Research Council as official representative of the American Ceramic Society.

Inter-Departmental Committee on Specifications for Refractories

The Bureau of Standards has been charged with the task of preparing specification s for refractories used by the various Federal Departments. The Bureau has asked the assistance of representatives of various industries to constitute an advisory committee and has also asked that the General Secretary of the American Ceramic Society serve as official representative of the Society. In conformity with this request the Board of Trustees has appointed Secretary Purdy as the Society's official representative.

All of the official personnel of the Refractories Division are serving on this Advisory Committee, having been appointed as official representatives of industrial groups.

The American Federation of Arts

This federation held its thirteenth annual convention in Washington, D. C., May 17–19, inclusive. Mr. Frederick H. Rhead, chairman of the Art Division, was appointed by President Riddle as delegate representing the American Ceramic Society.

Research Committee U. S. Potters Association

The meeting of the Research Committee of the U. S. Potters Association was held at the Bureau of Standards, Washington, D. C., on April 25th.

Tentative specifications for hotel ware were discussed and it was suggested that for vitreous ware the absorption for all hollow and flat ware, up to and including 8 inch dishes

should not exceed 1 per cent. No absorption requirement should be made for semi-vitreous ware. All ware, both vitreous and semi-vitreous should be required to withstand a quenching test from 175 degrees C to the temperature of tap water, repeated until it has been made five times. No items larger than five inches should be used for this test. The vitreous ware should be subjected to an impact test and should withstand a blow equivalent to 0.175 foot pound. No impact test should be required for semi-vitreous ware. Further work is to be done on the chipping, and abrasion tests and the effect of thickness upon the impact test is to be further investigated.

Mr. Larkins reported upon the use of cement for cases and the design of a kiln damper, Mr. Sproat on the use of cobalt sulphate as stain, Mr. Walker upon kiln dirt and saggers, Mr. Pence upon chemical tests for materials and Mr. Bleininger upon the question of normal water content of the materials and the control of the casting slip.

A discussion took place also of the possible standardization of the shapes and sizes of the most commonly used pottery items and the Bureau of Standards has agreed to undertake work along these lines. A comprehensive collection of different articles is to be arranged at the Bureau and a systematic survey of the situation attempted. It is hoped that at least for the purposes of the Government the shapes may be reduced in number and the sizes specified in a more satisfactory way.

National Research Council Division of Chemistry and Chemical Technology Annual Meeting

Excerpt from minutes of the annual meeting of the Division of Chemistry and Chemical Technology, held at the offices of the National Research Council, 1701 Massachusetts Avenue, Washington, D. C., April 24, 1922.

Present.—Messrs. W. D. Bancroft, A. V. Bleininger, F. G. Cottrell, Colin G. Fink, C. H. Herty, H. K. Moore, R. B. Moore, A. A. Noyes, Julius Stieglitz, E. W. Washburn. By invitation: Messrs. C. L. Parsons and C. J. West. Mr. W. Nichols acted as Secretary of the meeting.

Committee on Ceramic Research.—A. V. Bleininger, Chairman. Mr. Bleininger presented a brief report in behalf of his committee, stating that there had been no meeting of this joint committee during the past year, principally for two reasons—(1) the depressed state of the industries, and (2) the reorganization of the American Ceramic Society, which has expanded its activities and has created a permanent organization of well defined divisions. It is now proposed to offer to the National Research Council co-operation through a research committee composed of three members-at-large and one member chosen by each of seven divisions which represent the different industrial groups. As a result of this plan the present joint committee between the American Ceramic Society and the National Research Council should be discharged.

Mr. Cottrell then read a communication from the General Secretary of the American Ceramic Society, stating that the Society was now engaged in a complete reorganization, and that at the last meeting, February 27–March 3, in view of the contemplated changes in method of contact with the National Research Council, the joint committee between it and the National Research Council had been abolished, and that when the reorganization shall have been completed it is intended to make a presentation of this organization to the National Research Council with the purpose of developing the co-ordination in purpose and effort.

It was thereupon

Moved: That the report of the chairman be received and filed, and that the joint committee on Ceramic Research be discontinued.

Adopted.

Directory of Laboratories for Tests and Analysis of Ceramic Materials

A member of this Society wanted analysis made of some clays and after several unsuccessful enquiries sent his clays to England. Such enquiries come to the several federal bureaus and departments and to the ceramic departments of the Universities every week. Certainly there should be no difficulty in obtaining reliable tests and analysis of ceramic materials. There are several who are equipped to do such commercial testing.

The Board of Trustees of the American Ceramic Society has decided that the maintenance of a directory of laboratories in position to do commercial testing is one of the services which the Society should render. Those who will do such commercial testing are requested to give the Secretary's office (in confidence) a schedule of their facilities and charges. Members of the Society are asked to send in names of those by whom this notice will not be read.

The Secretary's office is now in co-operation with the U. S. Geological Survey in finding opportunities for such testing and it is intended that this co-operation shall be made general.

Here is opportunity for every member of the Society to co-operate in an enterprise for which there is an immediate demand. It is hoped the response to this appeal will be large.

On page 20 of the Advertising Section of the May issue there is a plan for classified advertising which will help to get these names before the public.

University Extension Courses

One of the first tasks of the Committee on Ceramic Education as provided by the amendment to the Constitution recently adopted, will be to develop the possibilities of University Extension Courses for persons employed in the ceramic industries. Dr. E. Ward Tillotson has been asked by the Board of Trustees to make a preliminary survey.

Here is an illuminating enquiry recently received.

> A little nigger "Carry-in-boy" in a Machine-Made Bottle Factory once made a suggestion that all of the mechanical genius had been over-looking for several years. The rest of that nigger's idea until he is 1256 years old may not be worth anything, and the one I want to spill at this time may not be either, but it can be disposed of quickly anyway.
>
> I got a list of the courses offered by the University Extension Division of University of Wisconsin recently to figure on some spare time work for myself, and it just occurred to me that the Glass Division of the American Ceramic Society could arrange with them for a selected course and endorse it for use by men in the factory like myself who never had the opportunity to take a resident school course. This, in time, would do the industry a lot of good.
>
> Regular subjects which the University of Wisconsin Extension offers that I notice are: "Heat," "Fuels," "Gas Producers" and "Compressed Air" in their Mechanical Engineering list, and "Elementary Geology," "Elementary Chemistry" and "Mineralogy."
>
> Could you not get such a course endorsed for men who do not know where to look for what will help them most?

Amendments to the Constitution

Out of 525 possible votes on the Amendments to the Constitution, 103 were cast with the following result:

Proposed Amendments	Yes	No
Wherever a representative of a Division or Section is indicated as a member of a committee, the words "selected by" shall be substituted for any phraseology used.	94	2
Article VI, Paragraph 1. "(10) Ceramic Education."	97	
Paragraph 13. "The Committee on Ceramic Education shall consist of a Chairman appointed by the Board of Trustees and one representative selected by each Division. This Committee shall make recommendations through the Board of Trustees for the betterment of ceramic education in institutions now established and for the encouragement of new departments of ceramics where the demand and facilities warrant."	97	1
Paragraph 14. "The Coördinating Service Council shall consist of the General Secretary, ex-officio chairman, and the chairmen of the Committees on Research, Standards, Geological Surveys, Data, and Ceramic Education. The Council shall have general supervision of the work of these Committees for the purpose of coördinating their work within the Society and with the work of other organizations on ceramic topics and problems."	101	1
Article X, Paragraph 1. "The Board of Trustees shall employ at suitable compensation an Editor of the Journal of the Society and an Advertising Manager, both of whom shall be nominated by the Committee on Publications to the Board of Trustees."	95	4

Each Amendment, therefore, is carried and, according to rule, at once becomes effective.

Membership Record

As might have been expected, the pace shown during and immediately after the Annual Meeting was too fast to continue. We have dropped a long distance to twenty-six new members in April. There is a gratifying side to this, however, in that thirteen of the twenty-six are Corporation Members. Supposing half of the members last month had been Corporation!

Also we call the attention of the general public to the record of the White Wares Division—eight new Corporation Members and three Associates. No other Division can compare with this, although each contributes some. The Heavy Clay Products Division has two Corporation and one Associate; the Enamel Division has one Corporation and two Associate; the Refractories Division has four Associate, and the Art and Glass Divisions have one each. There are two Corporation Members and one Associate not identified with any Division.

Analyses of the various industries have been undertaken by the office of the Secretary, showing the amount of representation in the Society held by each firm, and also showing the possibilities of the field. With this aid, and with renewed effort by officers and members, it should be possible to chalk up a better record next month.

One man alone is responsible for *six* of the Corporation and *one* of the Associate Members of the White Wares Division. He secured them by writing personal letters to a group of prospects. Another man sends in an average of one Corporation and one Associate Member *every month*. He does not make any noise but he writes *personal* letters.

How about writing two letters every day this month to persons you know who should be members? Have a sample copy of the new *Journal* sent to them and *write*.

New Members Received during April

ASSOCIATE

Armstrong, M. K., Hampton, Va.
Bentley, Fred, 72 Kelsey Ave., Trenton, N. J.
Bown, L. H., Buffalo, N. Y., General Manager, Buffalo Pottery
Butler, M. W., 14619 Coit Road, Cleveland, Ohio, Research Engineer, The Glass Coating Co.
Greene, Joseph F., 740 Pear St., Vineland, N. J., Kimble Glass Co.
Lodwick, J. A., 17 East 42nd St., New York City, American Arch Co.
Moodie, David M., Norwood, N. C.
Morgan, F. A., Anaconda Lead Products Co., Chicago, Ill.
Rivière, Mme. Jean, Jopyma Route du Cap-Brun, Toulon (Var), France
Seaton, Max Y., Sierra Magnesite Co., Porterville, Cal.
Vodicka, Albert L., Aetna Porcelain Enameling Co., 4701 Augusta St., Chicago, Ill.
Whipple, Allen D., 5241 N. Kimball Ave., Chicago, Ill.
Wildblood, A. F., 28 Wall St., Trenton, N. J.

CORPORATION

Batchelder-Wilson Co., 2633 Artesian St., Los Angeles, Cal.
Buffalo Pottery, Buffalo, N. Y.
Canonsburg Pottery Co., Canonsburg, Pa.
Canton Brick and Fireproofing Co., New Philadelphia, Ohio
Cook China Co., Trenton, N. J.
Crown Potteries Co., Evansville, Ind.
Interstate Corporation, Trenton, N. J.
Michigan Stove Co., Detroit, Mich.
National Lime Association, Washington, D. C.
Pope-Gosser China Co., Coshocton, Ohio
Stevens Bros. & Co., Stevens Pottery, Ga.
Western Electric Co., Hawthorne Station, Chicago, Ill.
H. R. Wyllie China Co., Huntington, W. Va.

Associates Elevated to Active Membership by the Board of Trustees, April, 1922

Abrams, Duff A.
Acheson, E. G.
Bachman, P. S.
Bacon, Charles C.
Baggs, A. E.
Bartells, H. H.
Beasley, H. C.
Bitting, A. W.
Brand, J. J. Fred
Bray, Archie C.
Brenner, R. F.
Buck, D. M.
Chandler, A. H.
Cooper, George W.
Crume, William H.
Dailey, Ernest W.
Dalton, Richard F.
Darlington, Homer T.
Davis, Harry E.
Donahoe, Frederick W.
Farren, Mabel C.
Flagg, F. P.
Flint, Francis C.
George, W. C.
Goodner, Ernest F.
Grant, W. Henry
Greenough, M. B.
Greenwood, G. W.
Hansen, J. E.
Helser, P. D.
Hill, Charles W.
Hill, James H.
Holmes, M. E.
Hower, H. S.
Hudson, Charles J.
Hunt, F. S.
Justice, I. M.
Keehn, C. C.
King, Earl O.
Knowles, Homer
Langworthy, H. S.
Larkins, Samuel
Leibson, J. S.
McDowell, S. J.
McGee, Earle N.
Manson, M. E.
Menne, L. H.
Merica, Paul D.

Moulton, D. A.	Schaeffer, John A.	Twells, Robert, Jr.
Muessig, C. N.	Schramm, Edward	Vincent, Harry S.
Parker, George W.	Smith, Perry A.	Wainford, R. H.
Pfalzgraf, Chas. F.	Smoot, C. E.	Walker, Chas. H.
Randall, James E.	Stone, George C.	Weller, S. A.
Reinecker, H. P.	Thomas, Richard G.	Young, Russell T.
Rusoff, Samuel	Thwing, C. B.	Zwerman, Carl H.

Who's Where in the American Ceramic Society

A note to the members: We try to keep the membership list constantly corrected. Naturally, however, changes of position and address are not known unless they are sent in. Sometimes we see notices in other periodicals touching the personnel of our membership. We always feel slighted when this occurs because we like to get the information direct. If we do not have correct addresses the Journal is not received, communications are lost, and both sides suffer. We wish members would make a point of notifying us when changes in address or position are made. It would help us to keep our records complete also if the company and position were always mentioned in such notification.

Robert E. Anderson is now associated with the Robertson Art Tile Co., at Trenton, N. J.

James L. Austin has recently accepted a position with the Carborundum Co., at Niagara Falls, N. Y.

George Blumenthal, Jr., has left the Bureau of Standards and is at Alfred, N. Y., where he will assist Professor Binns in the summer session of the Ceramic Department.

William B. Cleverly, formerly of Stoke-on-Trent, has become connected with the Carborundum Co. Ltd., at Manchester, England.

Paul P. Francais is now Enameling Superintendent of the A-B Stove Co., at Battle Creek, Mich.

H. W. Douda left the Bureau of Mines on April first and went to the National Fire Proofing Co., at East Palestine, Ohio.

Herbert Goodwin is superintendent of the Crescent China Co., Niles, Ohio.

H. W. Jackson has returned to DuBois, Pa., and is general manager of the Jackson Vitrified China Co.

T. A. Klinefelter, formerly superintendent of the Atlantic Terra Cotta Co., Tottenville, Staten Island, has gone to Trenton, N. J., where he is general manager of the pottery branch of the J. L. Mott Co.

G. Z. Minton, who is with the Pittsburgh Plate Glass Co., has been transferred from Creighton, Pa., to Kokomo, Ind.

William W. Paul has moved from Detroit, Mich., to Scranton, Pa.

A. E. Saunders has recently become Vice-President and Superintendent of the Oriental Art Glass Co., Chicago, Ill.

C. Saxton, formerly of France, is now agent in England for manufacturers of materials and apparatus, particularly for the glass industry. His office is at 35 Bedford St., Strand, London.

H. G. Schurecht has been connected with Mellon Institute, Pittsburgh, Pa., since April first.

C. A. Underwood, of the American Refractories Co., has been transferred from Valley, Wash., to Joliet, Ill.

On May 1, 1922, **R. T. Stull** was made Supervising Ceramist for the U. S. Bureau of Mines as a whole. He will have supervision in technical matters in ceramics, and related investigation of non-metallic minerals. He will have administrative as well as

technical supervision of field work in the kiln investigation carried out in co-operation with the four heavy clay products associations, including the car "HOLMES" and its crew. He will make his headquarters at Columbus, Ohio, but his services are available for consultation by all branches of the Bureau concerned with ceramics.

George A. Bole is Acting Superintendent of the Ceramic Experiment Station, at Columbus, Ohio, and as such acts in an advisory and consulting capacity to the Station in all of its ceramic work.

Say it with Words

We have been comparing the advertising pages of some numbers of the *Journal of the American Ceramic Society*. The figures are given below:

Space	Jan. 1918	Jan. 1919	Jan. 1920	Jan. 1921	May 1922
Full pages	4	7	6	8	11
Half pages	6	7	9	7	12
Quarter pages	5	4	3	6	11
Eighth pages	0	0	0	1	3
Total	8 1/4	11 1/2	11 1/4	13 1/8	20 1/8

This is a considerable increase but not as large as it should be, and readers of the *Journal* are partly to blame. When you write to a manufacturer, do you tell him where you saw his advertisement? This is little trouble for you, but it helps the advertiser and the periodical mightily.

One of our advertisers says that while he believes his advertisement brings him business, he has no positive proof because no one has ever said that the advertisement was seen in the *Journal of the American Ceramic Society*. Will you notify your purchasing agent, or put it in your hat, to mention the *Journal* to advertisers?

Official Personnel of Divisions 1922–23

	Art	Enamel	Glass	H. Clay Prod.	Refractories	Terra Cotta	White Wares
Chairman	F. H. Rhead	B. T. Sweely	J. C. Hostetter	C. F. Tefft	J. Spotts McDowell	A. F. Hottinger	F. K. Pence
Vice-Chairman	H. S. Kirk		A. R. Payne	D. F. Stevens	E. H. Van Schoick		
Secretary	M. C. Farren	R. R. Danielson	A. E. Williams	M. B. Greenough	Fred A. Harvey	R. L. Clare	C. C. Treischel
Committee on Research	F. H. Rhead	R. R. Danielson	E. C. Sullivan E. W. Washburn R. B. Sosman *	O. W. Renkert R. T. Stull G. W. Shoemaker Warren Griffis Paul E. Cox R. K. Hursh	R. M. Howe E. N. McGee G. F. Bissell W. E. Dornbach F. A. Harvey S. M. Kier	E. C. Hill Major Gates	F. K. Pence L. H. Bown F. S. Hunt V. S. Schory Ira E. Sproat O. O. Bowman, 2nd August Staudt Leslie Brown C. C. Treischel
Committee on Standards (*a*) Tests (*b*) Products	W. J. Stephani C. F. Binns	E. P. Poste D. F. Riess	(*a*) A. E. Williams W. F. Brown J. H. Forsyth (*b*) A. W. Bitting H. K. Kimble C. W. Parmelee R. J. Montgomery	P. H. Bates W. G. Worcester S. M. Duty R. A. Horning S. Geijsbeek	R. M. Howe E. N. McGee	(*a*) C. W. Hill D. F. Albery (*b*) J. L. Carruthers	H. S. Spurrier F. S. Hunt
Committee on Data	Conrad Dressler	R. R. Danielson	G. W. Morey W. C. Taylor G. E. Barton	H. G. Schurecht	C. W. Parmelee	T. A. Klinefelter	C. C. Treischel
Committee on Membership	W. W. Wilkins	W. C. Lindemann	E. W. Tillotson Jas. Gillinder W. S. Williams	D. F. Stevens H. S. Vincent J. E. Randall H. S. Langworthy J. J. F. Brand	W. E. Dornbach I. A. Krusen A. B. Christopher M. F. Beecher Mark Sheppard M. G. Babcock	W. D. Gates G. M. Tucker A. L. Gladding	Ira E. Sproat
Committee on Rules	F. H. Rhead	J. B. Shaw	W. M. Clark W. A. Yung C. C. Rand	C. B. Harrop R. L. Hare W. W. Ittner S. L. Galpin	E. H. Van Schoick Geo. Fisher	R. L. Clare	August Staudt
Rep. on Committee on Nominations	Paul E. Cox		C. O. Grafton	C. F. Tefft	A. F. Greaves-Walker	E. C. Hill	Herbert E. Goodwin
Councilors	Hewitt Wilson W. D. Gates Fredk. Carder Ira E. Sproat	R. D. Landrum D. F. Reiss W. C. Lindemann H. F. Staley	H. L. Dixon C. L. Grafton H. W. Hess J. W. Wright	W. N. Cary E. W. Dailey Geo. A. Bole Eben Rodgers		Geo. P. Fackt W. J. Stephani M. C. Gregory	

* Glass Division Committee on Refractories. D. W. Ross, Chr., C. O. Grafton, A. S. Zopfi, C. E. Fulton.

NOTE ON REFRACTORIES ENGINEERING[1]

By W. E. Dornbach

ABSTRACT

A brief outline of training necessary to fit one for work as a Refractories Engineer. Nature of the work, its present-day importance and one verbal illustration of the work of such an Engineer.

Refractories engineering, that highly specialized branch of ceramics engineering, while not exactly a new profession, still in a sense might be called new inasmuch as its importance in the industry is just beginning to be truly appreciated. Every now and then we hear of a student in one or the other of our excellent ceramic engineering schools, who through broad vision or the advice of some real well wisher, has elected a special course of study in Ceramic Engineering which will fit him to specialize in the branch which we have under consideration. Our ceramic schools are well equipped for this work but it remains for the student to draw from the courses offered the essentials to make him a real refractories engineer. These essentials are a careful study of the principles of mechanical and electrical engineering; a thorough mastery of the work offered in metallurgy and a complete course in ceramics, with particular attention to refractories. The writer acknowledges that this is a very stiff curriculum and one that can not be carried out in the usual four-year college course unless the student is of exceptional ability. To specialize one must either put in additional time in college or the research laboratory or spend years in the actual pursuit of his special line. It is a sacrifice of time which is justified by the opportunities afforded in the end.

Refractories engineering is work usually of a consulting nature, or has been, with some exceptions, up to this time. It is now being employed as a profession in a wider range of work. Large refractories manufacturing concerns employ refractories engineers to work out difficult refractories problems that can not be definitely solved in the laboratories. Large steel works, copper and other metal working and refining industries also are awakening to the fact that competent refractories engineers are necessary to assist in the proper conduct of their manufacturing processes. In these instances the refractories engineer's work is similar to a doctor's. He, through his mechanical, electrical and metallurgical knowledge, diagnoses the faulty practice, determines why this refractory lining, roof or bottom is failing to give the proper service and then describes the cure, watching carefully the selection of materials and seeing that they are properly placed in the furnace or whatever the apparatus is upon which he is working. This can be nicely illustrated by the experience of one of the industry's most competent refractories engineers a few months ago. A large copper refinery, of international importance, had been using a reverberatory fired by hand with coal thru the means of a Dutch Oven. The heat in the re-

[1] Refractories Division, St. Louis Meeting, Feb. 28, 1922.

verberatory was about 2600°F under this process. The bottom was of silica sand, the side walls of magnesite brick and the roof was laid up of heavy silica shapes making it twenty inches thick. This company found that by eliminating the Dutch Oven and by feeding powdered coal direct to the reverberatory they could make one furnace take the place of four as operated under the old practice and that they could perfect a saving of 28% of the fuel formerly consumed. The result was that instead of obtaining 2600°F in their furnace the temperature increased to about 3200°F and the heavy silica roofs quickly burned out. Furthermore where the silica bottom and the magnesia brick joined, the magnesia brick quickly disintegrated through the attack of the silica at the increased temperature, leaving an unsupported side wall, which was liable to fall at any time, and removing all lining protection where the magnesia brick had disintegrated. This was an experience which none of the old and tried employees of this particular smelting company had ever seen before and they were at a loss as to how to remedy it. Finally our friend the refractories engineer was called on the job, with the result that in a very short time he properly diagnosed the trouble and prescribed the cure, which was highly successful. Perhaps the "cure" might be interesting: A thinner roof was recommended, namely, one of 12″ shapes, thin enough to allow thorough radiation, the release of the intensified heat against the crown, therefore lengthening the life of the silica brick. A magnesite bottom was recommended and installed for metallurgical reasons and thereby the silica bottom, which had such a ruinous effect on the magnesite side walls, was done away with, and the disintegration of the magnesite brick stopped. The recommendation of the magnesite bottom, alone, saved this company an immense amount of money as a purer product resulted, entirely elimiating the use of the blast furnace later in the process. This is just one of a hundred or more cares of refractories engineering that has come to the writer's attention since he has been interested in this subject.

The constant demands made upon the metallurgical industry for a better product, the improvements in furnace construction, the high price of fuel, labor and equipment, all have tended to influence remodelling of old furnace equipment and the development of new and more efficient furnaces. This all means work for the refractories engineer as he is truly the court of last appeal when a radical change or a new furnace is perfected. It is as truly important that a lining be properly fitted to a furnace and process as it is that a potter produce a glaze that fits perfectly to his body or bisque. The advent of the electric furnace has probably had more to do with the development of the refractories engineer than any one type of furnace. Every now and then we hear of a new type being perfected or an old type being put to a new use, where a new lining must be installed. Rule of thumb methods are still, sad to say, being used in a great number of metallurgical and non-

metal producing plants where high grade refractories are used or abused. This method can not survive the demands which our present-day competition makes on the furnace user. Why line a cupola with expensive basic refractories when low priced fire-brick will even better answer the purpose, just because it has been the practice at this particular plant to do this? This is an actual condition which came under the writer's observation, and he leaves it to the reader to estimate the operating costs on this cupola. Are refractories engineers needed? Most emphatically yes. And the time will shortly arrive when more young ceramic engineers will enter this most important field.

Discussion

By A. F. Greaves-Walker.—Mr. Dornbach's paper brings out quite forcibly the need of the refractories industry for specially trained engineers. The colleges give an excellent opportunity for training such men, but it is, of course, more or less up to the men themselves to determine whether to take up this work and select their courses accordingly.

The particular requirements of a refractories engineer are a good ceramic training with special emphasis on refractories; a thorough knowledge of metallurgy and metallurgical furnace design; a good grounding in electrical engineering in order that pace may be kept with the rapidly developing electric furnace; a thorough knowledge of the principles of combustion, furnace design and fuels, and a good knowledge of geology. This latter is required because of the necessity of knowing the ores, fuel and raw materials with which the engineer has to deal.

In the past few years there has been a constant demand for men with this training in both the refractories and metallurgical industries, but there are no trained men available. It has even become necessary to have engineers on the sales forces of the refractories companies due to the demand of the consumer for salesmen who could diagnose his requirements and sell him the proper refractories.

With such an excellent opportunity for young men in a comparatively new field, it is hoped that more of our ceramic students will grasp it and take up the new work.

EXTENSION WORK[1]

By Paul E. Cox

ABSTRACT

The work in Engineering Extension at Iowa State College has been furthered by popular lectures supported by work on the potter's wheel, thereby getting before 40,000 members of Women's Clubs the fact that the ceramic profession is a vital factor in home life from many angles. It is shown how easily and cheaply such development work can be done.

In the late fall of 1920 Mrs. Lillian Crowley, Des Moines, Iowa, applied to the writer in behalf of the General Federation of Women's Clubs for

[1] Art Division, St. Louis Meeting, Feb. 28, 1922.

data for a paper to be printed in the Des Moines Register in the page devoted to things of interest to women. This came about for the reason that Iowa State College has a very large Home Economics Division and many of the young women come into the Department of Ceramics for training in pottery making, with the expectation, of course, that this work may prove of service to them in their teaching work later on. Mrs. Crowley became interested as is the case with most people in the work the writer happened to be doing on the wheel and an invitation was extended that brought about the extension work to be spoken of.

The writer built a potter's wheel of a special sort, so arranged that all the parts could be taken down and boxed up in the "crib" of the wheel, so that easy shipment could be had, the "crib" being the container for the rest of the machine. This makes a package of about 350 pounds and when the wheel is set up the machine is a rather rough-and-ready specimen of the old-fashioned kick wheel of the sort used by the country shops of stoneware pottery days. Clay is then carried along by the writer and with the few simple tools needed for such work it is possible to demonstrate the process of forming a vase in the rooms selected by the club women as a place for the show.

The first talk was in Des Moines under the patronage of the Fine Arts Association and this talk was repeated this year again. With the newspaper notices to suggest it, the Department of Engineering Extension head, Professor Faber, saw that a new activity was ready made for him and the writer has delivered from one to three talks a month all the year and has been compelled to refuse many other invitations, because of the fact that women can not readily put aside household cares on Saturdays and teachers have classes in the week days that interfere on their side with mid-week engagements. It is plain to be seen, however, that such work, properly handled, is easily a way to bring the knowledge of what ceramics folks are doing to a very large circle of people. In Iowa this work extends a knowledge of ceramics as an engineering profession to an organization consisting of 40,000 women, most of them mothers of sons and daughters who are potential students of ceramics or else potential consumers of the products of the ceramic arts and manufactures.

The wheel is sufficiently out of date so that it is a great attraction to nearly every person because it is no longer a familiar tool. With the wheel, a few lantern slides and a popular talk it is easy to hold an audience for two hours, and while no charge is made for the service, other than expenses, the writer has been gratified by the reports that come in about the interest shown, and by the desire to have this service in the several little cities of Iowa.

The talk deals not with art pottery but with pottery in general and from the standpoint of body composition and technical considerations generally.

Naturally the talk is reduced to simple terms, and is calculated to bring up the elderly lady with the heirloom with a question showing her pride in its possession. The real idea is to get before each group exactly what the field of ceramics covers, how to select dishes for the household use, and what the American and studio art potteries have to make the home more interesting. Out of this ought to grow benefit to the ceramic profession generally, as these women are the home makers of a commonwealth. And out of it ought to develop interest in the product of those interested in the Art Division, as every vase offered for sale will have more interest after common Iowa shale has been formed before them into pottery which can be handled and talked about with the maker. The pottery is brought to them instead of their visiting the pottery. And the shale chosen is one widely advertised as being used in a building block, so that mention of the source of the raw material brings home to them the lesson of what training can do with very simple material. Not yet has the writer failed to have to answer that water and Iowa shale made the mixture used.

The reaction on the Iowa State College is of less interest to those not of that institution but it has been found well worth while to have this work done and the authorities recognize the advertising value of this sort of thing. In token of this recognition the plan is being urged of the establishment of a studio pottery, with a competent artist doing the design work, who will use a part of the time to train others to make up a staff of several workers. This is decidedly an endorsement of what the Art Division is preaching, for this work is being initiated in the Engineering Division with the frank acknowledgment, or rather with the far-sightedness of a good administrator, that engineering and all other arts and sciences are mutually dependent one on the other, and that the young man or woman with a bent for crafts work needs direction and the chance to have it, whether it be to build a better looking machine or a better looking vase.

It would seem therefore that in every community similar extension work could be developed. The person is unwise who does not see the tremendous influence that women have in American life, for women are the great purchasing mass after all. Women can best be reached in the interests of ceramics as a profession, through the Art Division group. It is this idea therefore that prompts the writer to submit a paper hardly of a character to deserve attention in a body like the American Ceramic Society, otherwise. It should be noted, however, that few students enter any college unfamiliar with what the names "civil engineer" or "chemical engineer" or other engineering professions' names have to do but certainly out of the several hundreds entering Iowa State College each year there are few to whom the word "ceramics" has a meaning of any sort and a canvas of the membership of the Society would show a considerable number who had taken up the study of the profession because of having their curiosity excited by seeing

interesting work going on where that unfamiliar word was being used by a small but busy group of people. The extension work has been done cheaply and effectively and has reached directly and indirectly a wide circle of household managers. Teachers of art in high schools and colleges have been eager listeners and there is a great and real interest in exactly what the Art Division proposes to do. And this that the Art Division proposes to do will get before a great public what an influence the ceramist is to be and has always been in daily life. In other words the Art Division can very well be the publicity department of the American Ceramic Society so far as the lay people are concerned.

DEPARTMENT OF CERAMICS
IOWA STATE COLLEGE
AMES, IOWA

ITEMS OF COST FREQUENTLY OVERLOOKED[1]

BY F. T. OWENS

There will be some of you who will no doubt wonder what particular items of cost there could be that are not included in your books and it is possible that none of you have these to contend with, but it is a matter of record that most manufacturers fail to consider some of the items that are causing serious losses and are often overlooked.

Many manufacturers are enjoying a false security because they do not keep an absolute record. For instance, in the manufacture of brick or hollow ware, a certain percentage is placed on the dryer cars without being recorded with the thought that this will take care of all breakage due to the drying and burning. Would it not be much better to have an absolute count, keeping a record of the breakage in dryer and kilns and find out just what the breakage is? For it is only by giving these matters due consideration and studying their importance that we endeavor to correct them.

Another source of loss comes in the lack of proper sense of proportion between costs and selling price, but before taking that up, it might be well to consider the question of costs from another standpoint. Assume that a machine production of 987,000 brick for the month is reported at a cost of $16,650.69. This is the machine production and shows us a cost of $16.87. However, we find a dryer breakage of 2%, a kiln breakage of 5%, which decreases the net production to the figures of 917,910 brick and increases the $16.87 cost to $18.47 per M. We find also that 10% of the production are seconds, which have to be sold at $2.00 less than the actual cost price, thus raising the cost of the first quality ware to $18.43, which is a net difference of $1.56 between the figures we first had and those we get finally.

On the first figures of $16.87 we would add sufficient to bring the selling

[1] Heavy Clay Products Division, St. Louis Meeting, Feb. 28, 1922.

price to $19.50. This would allow us a profit of 12.8%, but on the revised figures we find the profit is only 5½%.

In the figures quoted above there is nothing for idle time throughout the year and the manufacturer who sits down and figures the cost for one month and believes that he can sell for the succeeding ninety days on the basis of that first month's costs is seriously fooling himself.

What manufacturing business can afford to push ahead, put in improved methods and machines on a selling price of 12% above cost of production? The smallest margin that any manufacturer should consider should be 20%. In other words, if the unit of sale costs $16.00, then it should sell for $20.00, which allows that 20% of the selling price for profit above cost and I think that those of you who have been in the brick business will agree with me that a four dollar profit at the factory end is something we have rarely heard of, except in a few cases where a highly specialized brick is being considered. Aside from the war times, the hollow tile manufacturers and the common brick manufacturers have found themselves in a no more favorable situation.

A basis of costs figured on any one month's production can not show you the results unless continuous operation throughout the entire twelve months of the year can be had. There may be some who can have a clay plant idle without having any expense attached, but such a plant would be worth little when it was started up anew, for some one must be looking after it day by day or a very serious depreciation comes so that when it is time to start the plant heavy repair bills must be met. It is fair to assume that the average plant producing 120 tons of material per day has an overhead of approximately $1000 per month in interest charges, insurance, up-keep, watchman, heating, water, etc., and if such a plant is down for three months, then the overhead of those three months must be distributed throughout the cost the entire year. Unless this is done the manufacturer is going to find himself disappointed when the annual balance sheet is made up.

Depreciation must be given due consideration and if this is not done, after a term of years the manufacturer will find himself with a plant worth less than the representation in capital stock on his books. An item of depreciation is properly chargeable in your costs and should appear there. If this is not done, it can only mean a loss in the long run.

There is another item of cost which should have very careful attention and this is in the off-quality material. Some of you may not be troubled with this, but then again, others find it quite a problem. Assume for the moment that you are making a material on which you have determined your cost to be approximately $20 per unit, after giving consideration to your second quality ware and breakage. The experience in the past has been that, on a cost of $20, one dollar or one dollar and a half would be

interesting work going on where that unfamiliar word was being used by a small but busy group of people. The extension work has been done cheaply and effectively and has reached directly and indirectly a wide circle of household managers. Teachers of art in high schools and colleges have been eager listeners and there is a great and real interest in exactly what the Art Division proposes to do. And this that the Art Division proposes to do will get before a great public what an influence the ceramist is to be and has always been in daily life. In other words the Art Division can very well be the publicity department of the American Ceramic Society so far as the lay people are concerned.

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ITEMS OF COST FREQUENTLY OVERLOOKED[1]

BY F. T. OWENS

There will be some of you who will no doubt wonder what particular items of cost there could be that are not included in your books and it is possible that none of you have these to contend with, but it is a matter of record that most manufacturers fail to consider some of the items that are causing serious losses and are often overlooked.

Many manufacturers are enjoying a false security because they do not keep an absolute record. For instance, in the manufacture of brick or hollow ware, a certain percentage is placed on the dryer cars without being recorded with the thought that this will take care of all breakage due to the drying and burning. Would it not be much better to have an absolute count, keeping a record of the breakage in dryer and kilns and find out just what the breakage is? For it is only by giving these matters due consideration and studying their importance that we endeavor to correct them.

Another source of loss comes in the lack of proper sense of proportion between costs and selling price, but before taking that up, it might be well to consider the question of costs from another standpoint. Assume that a machine production of 987,000 brick for the month is reported at a cost of $16,650.69. This is the machine production and shows us a cost of $16.87. However, we find a dryer breakage of 2%, a kiln breakage of 5%, which decreases the net production to the figures of 917,910 brick and increases the $16.87 cost to $18.47 per M. We find also that 10% of the production are seconds, which have to be sold at $2.00 less than the actual cost price, thus raising the cost of the first quality ware to $18.43, which is a net difference of $1.56 between the figures we first had and those we get finally.

On the first figures of $16.87 we would add sufficient to bring the selling

[1] Heavy Clay Products Division, St. Louis Meeting, Feb. 28, 1922.

price to $19.50. This would allow us a profit of 12.8%, but on the revised figures we find the profit is only 5½%.

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There is another item of cost which should have very careful attention and this is in the off-quality material. Some of you may not be troubled with this, but then again, others find it quite a problem. Assume for the moment that you are making a material on which you have determined your cost to be approximately $20 per unit, after giving consideration to your second quality ware and breakage. The experience in the past has been that, on a cost of $20, one dollar or one dollar and a half would be

plenty to add for profit. Now let us see what happens. In the production of a million of first-quality ware we get 200,000 that are off shade or off quality so that the unit price drops to $18 per M. This means a two dollar loss or $400, which must be considered in the selling price of the strictly first-class ware, or a matter of $.50 per unit. This point has been missed in the past and is being missed by a great many manufacturers today and accounts, in many instances, for the disappointment of the Board of Directors when they consider the profits for the year and find that instead of a 10% dividend they can only make it three or four.

At this point it might be well to consider another problem that faces us today. The indications are that the next five years will see some wonderful developments in the manufacture of heavy clay wares and it is not beyond the realm of possibility that many of the plants in service today will be out of date five years hence. This brings to our minds the thought, should we not provide for obsolescence as well as depreciation? Assume that a plant stands at $100,000 today and that thirty thousand of this investment will become obsolete in five years. Should we not make provisions to take care of this? Otherwise, how will the improvement be paid for when it must be put in? We would find serious difficulty in providing for this day under our present income tax law and it is a serious problem that should have our careful consideration and be brought to the attention of those who can afford us relief.

We have heard a great deal about deflation and the reduction of living costs, etc., but those of us who have had to travel much during the last year have found, in many instances, costs have not receded any from the war time rates and we naturally wonder why. If you will give consideration to the following thought, we believe you will see why. We have in this country two large strings of hotels. With one of these it is the purpose of the managing board to build one new hotel each year from the profits of the others and as such a hotel costs today about $2,000,000 fully equipped, you can see that in order to have $2,000,000 net gain over dividends to put in a new enterprise they must pay our good old Uncle Sam a handsome income tax. To do this they are taking it from the man who finds it necessary to travel from point to point to earn his daily bread. If you have figured out on your plant that thirty thousand dollars made in 1922 will afford the return on the capital invested that you think is adequate, are you figuring to earn enough for Uncle Sam so that you may be allowed to pay the desired amount to your stockholders? If not, you had better give this consideration, else you will find when you come to make up your balance sheet that the profits have again vanished.

Some time ago the writer had occasion to check up some figures on a plant to see why burning costs had suddenly risen and after a careful comparison was made of a number of kiln records, it was found that nearly

10% less ware was being placed in the kilns than had formerly been done, with a consequent sharp rise in burning costs.

It is only by keeping very careful records and then checking the records of one period against those of another that we can find the reason for rising costs and a careful analysis should be made at all times of the costs as they are shown from time to time so that occurrences, such as we have noted, may be quickly brought to light and corrected.

If we could imbue the employees with the thought that they are working with the material, which while only raw clay to start with, has added to it gold in the shape of labor as it goes from process to process, they might consider it from a different standpoint and use more care in its handling and take more pride in seeing that the final result is that which is hoped for.

We must get our men away from the thought of being ordinary mud mixers and get them to see, if possible, that working in clay to produce hollow ware, floor tile, roofing tile, face brick, common brick or any similar ware is just as honorable as the production of the finest chinas or glass ware.

In closing allow me to urge upon you the adoption of uniform cost system with your fellow manufacturers so that when you come to compare costs (and this I urge upon you most strongly), you will be talking about the same thing in exactly the same way and when the golden day arrives that we can sit down and talk about our costs, each of us talking on about the same basis, then indeed we will be making a greater progress than has been shown heretofore.

NOTES ON GREEN STAINING OF CLAY WARE[1]

By C. W. Hill

The cause of yellow-green staining which sometimes occurs on ceramic products on exposure to weather has usually been attributed to compounds of vanadium. The explanation probably had its origin in the investigations of Seger who appears to have established the presence of vanadium in the material examined by him. The view has been perpetuated in the literature by several American and English ceramists and is that of nearly all the ceramists with whom the subject has been discussed.

A case was brought to the writer's attention several years ago of green stain on ware made from clay which was known to contain a small amount of pyrites. A sample of the stain was digested with various acids but the solution failed to give a test for iron. The dried stain was fused with an alkali and the fusion dissolved in hydrochloric acid. This solution gave a heavy iron test. Upon neutralization with ammonia a white flocculent precipitate was obtained, indicating that the iron had been combined with alumina or silica.

[1] Terra Cotta Division, St. Louis Meeting, Feb. 28, 1922.

This test has since been repeated with a positive test for iron whenever examples of green staining could be found.

The stain is dissolved by oxalic acid solution or by a solution of alum acidified by sulphuric acid, the latter having been brought to our attention by Mr. George Facht. Either of these solutions if sufficiently concentrated gives an iron test.

The tendency toward green staining is present in buff burning clays, which burn "soft," that is, have a high absorption. We understand that manufacturers of buff face brick overcame the difficulty either by burning at a higher temperature or by addition of a tighter burning clay. Whether the first remedy is due entirely to the decreased absorption of the product with decreased leaching action of water or in part due to the fixation of the iron in a less soluble compound, we are not prepared to say. The point is doubtless one of theoretical interest and not of practical value. When the ware is covered with a slip the green staining may be avoided by use of a "hard" slip, without resorting to higher burning.

The absence of iron in Seger's analysis as well as certain differences in chemical behavior and appearance of the stain he describes would indicate that this was of a different nature than the stains we have investigated. Our experience, however, would indicate the desirability of testing for iron by fusion before assuming that vanadium is the cause of any green stain. We are inclined to believe that with Eastern and Central clays the stain is probably entirely due to iron. We have not tested the stain on Western clays which may possibly contain vanadium and resemble the clay tested by Seger.

DISCUSSIONS OF "THE ADAPTABILITY OF THE GAS FIRED COMPARTMENT KILN FOR THE BURNING OF CLAY PRODUCTS"[1]

By C. B. Harrop:—Mr. Richardson is advocating the use of a kiln which, under certain conditions and for certain wares, is a very desirable type and is surely going to be installed for white wares in the near future.

Provided the initial investment is not prohibitive, a fuel saving of over 50 per cent will enable the owner of this kiln to show the stockholders a neat increase in annual profits or else it will enable him to cut the price of this product to a point that will be of very serious concern to his less progressive competitor.

The author calls attention to the fact that when describing the performance of the car tunnel kiln, "comparisons have always been made with the old periodic kiln and not with the latest developed continuous kilns of other types." He then proceeds to compare the performance of the compartment kiln, which he is advocating, with the same "old periodic kiln."

[1] Richardson, *Jour. Am. Ceram. Soc.*, **5**, 254 (1922).

Personally, I feel that a comparison of either type of continuous kiln with the periodic kiln is perfectly justifiable, for it is this wasteful kiln that we are all anxious to see supplanted with a modern and more economical structure. As a matter of fact, I doubt if there is a clayworking plant in the United States where both the moving-fire-zone continuous kiln and the car tunnel kiln can be found, while almost invariably are there periodic kilns at the same plant with either type of continuous kiln. If we compare both types of continuous kiln with the periodic kiln, we can readily compare the performance of the two continuous kilns with each other.

The author states that the continuous compartment kiln for heavy wares operating on the same yard with periodic kilns has shown a fuel saving of *more than 50 per cent.* This is a saving that should attract the attention of every progressive manufacturer. However, it should be mentioned here that on a number of car tunnel kiln installations handling white wares, the fuel saving, over former periodic kiln operation, is 75 per cent and even higher in some instances.

Under No. 4 of the author's summary, he states that in a car tunnel kiln, the capacity is limited because a "strong draft does not distribute the heat properly." I do not believe that he is justified in making this statement, as the writer can exhibit several installations of the car tunnel kiln, operating at high production, in which the temperature variations over the cross-section of the ware are practically nil.

The author makes the statement that repairs can be made more readily in the compartment kiln than in the car tunnel kiln. It should be pointed out in this connection that, as the temperature in any part of the tunnel kiln is held practically constant at all times, expansion and contraction trouble are conspicuous by their absence. The car platforms are the only parts to suffer from this action, which is so prevalent in periodic and moving-fire-zone continuous kilns and they are attended to on the outside and interfere in no way with the operation of the kiln.

The author does not allude to the cost of installing a compartment continuous kiln. Figures on the cost of this kiln for a given capacity would be very interesting and valuable for comparison purposes.

By A. F. Greaves-Walker:—There can be little question but that it has been amply demonstrated that the gas fired compartment kiln can successfully replace the present types of periodic kilns used in any branch of the industry with an assured saving of at least 50% in the cost of operation.

Many kilns of this type have been built in this country for use in burning heavy clay products, the majority of which are or have been successfully operated. Failures or partial failure or the failure to come up to expectations have been due, in every case the writer has investigated, to poor construction or failure to follow good engineering practice.

There is a great question as to whether the railroad tunnel kiln will ever come into general use in the heavy clay products industry due to the obvious limits on the capacity and the space required for installation. In this branch the continuous kiln is, at present, the only solution of the burning problem.

However, it is the writer's opinion that the railroad tunnel kiln has demonstrated that it is the ideal type for the pottery industry and while the continuous compartment type may be used in isolated instances, it will never become popular.

DISCUSSION OF "PHYSICAL DEFECTS IN TANK BLOCKS"[1]

By W. Angus McIntyre:—Fig. 1. Two sets of trend lines are seen. The diagonal ones correspond to the laminations and the less permanent horizontal set is found only toward the sides of the block.

Fig. 1.

[1] Loomis, *Jour. Am. Ceram. Soc.*, **5**, 102 (1922).

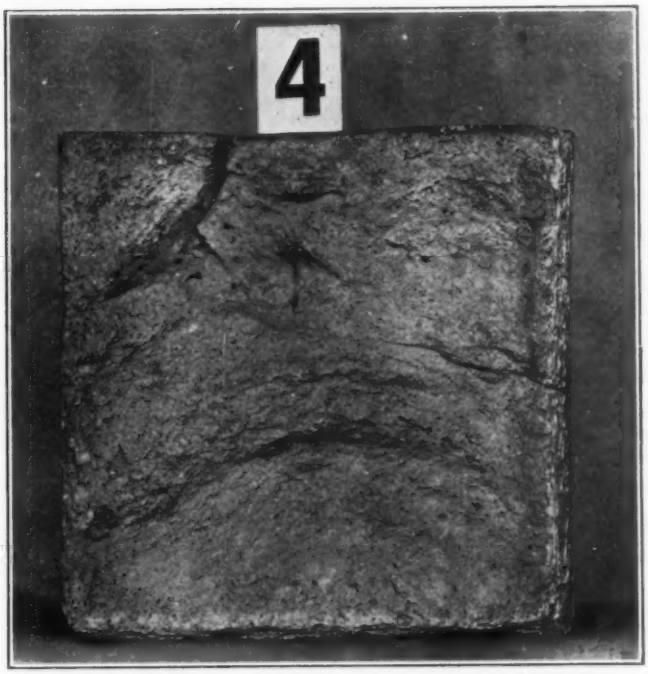


FIG. 2.

FIG. 3.

Fig. 2 is typical of most of the blocks I have examined. In addition to several cavities and numerous pinholes irregularly arranged there are concentric laminations which gradually flatten out toward the top and for the last $^3/_8$″ become quite horizontal when enlarged up to 3–4 diameters.

Fig. 3 is a fragment of a block which has stood up fairly well in practice. In this the pinholes and cavities are just as numerous as in the previous

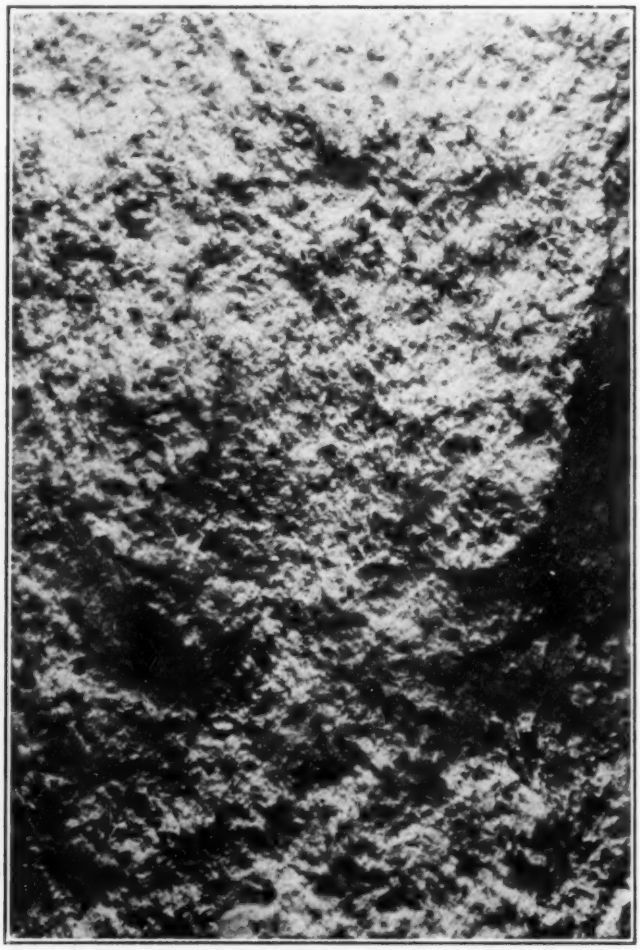
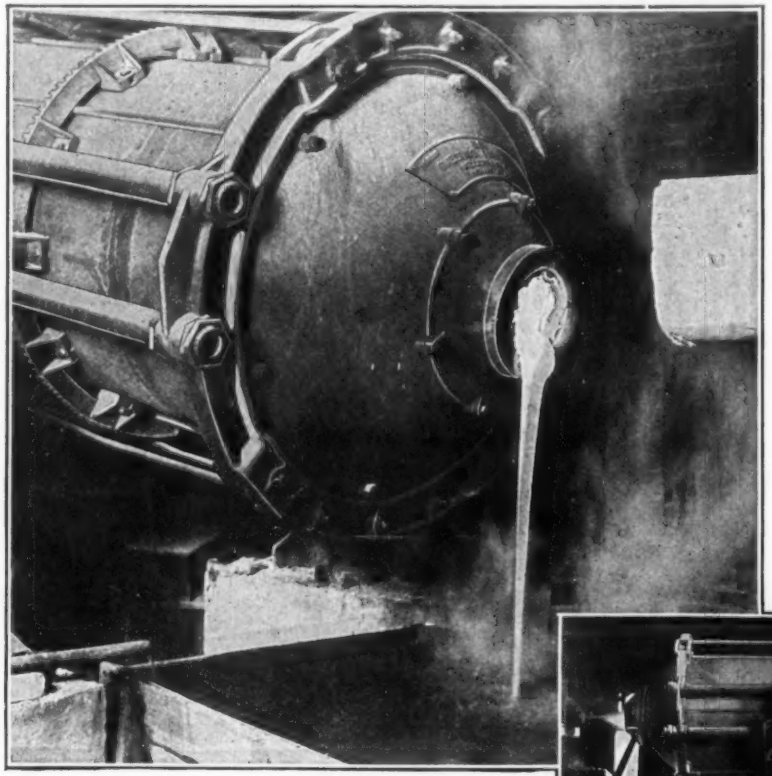
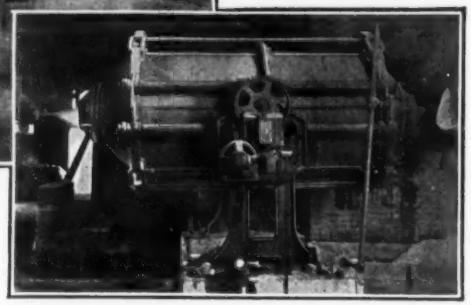


FIG. 4.

specimen, but even on enlarging only one set of trend lines can be seen and they bear no apparent relationship to the edges of the block.

In attempting to prepare microscopic sections of these blocks it was found that the specimens tend to fracture much more readily in the direction of these various trend lines and the structure appears to persist throughout the blocks down to a very fine scale.





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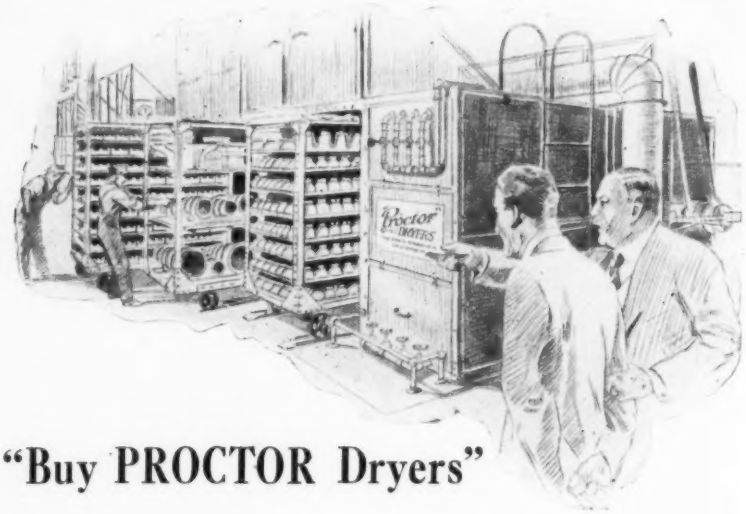

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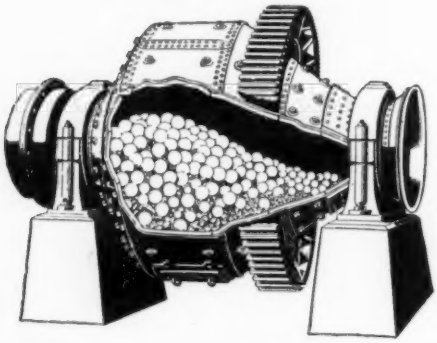

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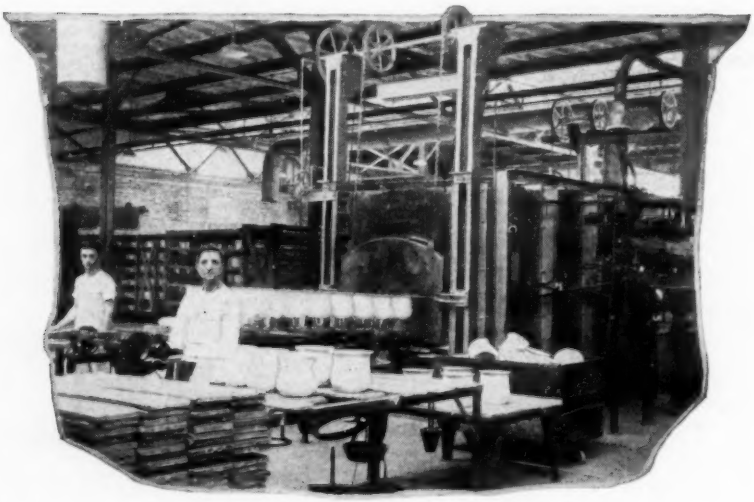

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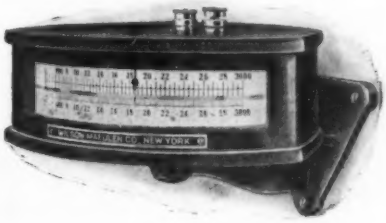

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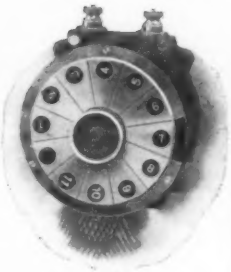

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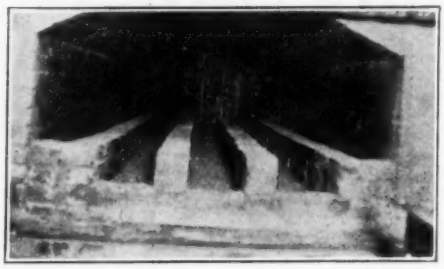

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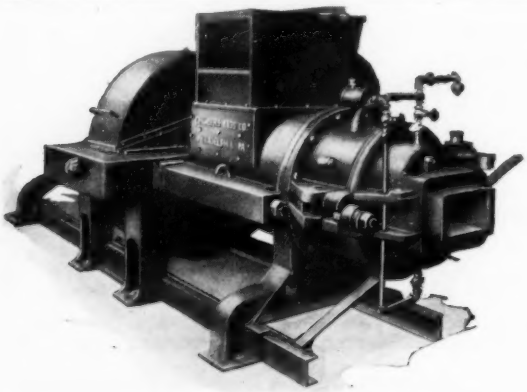

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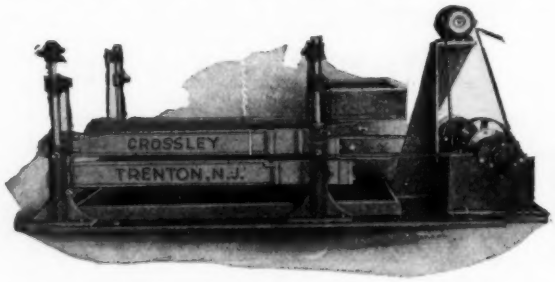

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